Ormat General File

1	PGV to DLNR Requesting Approval of Amendment to Plan of Operations	1/18/89
2	Amendement to Plan of Operation for PGV	1/18/89
3	Designation of PGV Agent	1/18/89
4	State Parks Review of PGV Amendment to Plan of Operations	1/25/89
5	County of Hawaii Receipt of GRP Application from PGV	1/25/89
6	DLNR Acknowledging Receipt of Amendment to the Plan of Operations	2/22/89
7	Changes to PGV GRP Application	2/27/89
8	OCEA Review of PGV Amendment to Plan of Operations	2/27/89
9	DLNR Approval of Amendment to Plan of Operations	3/10/89
	~~GRP Application Amendment~~	~~3/89~~
10	Additional Information on GRP Application	3/28/89
11	Well Modification Permit Request	5/22/89
12	DLNR Comments on PGV GRP Application	6/5/89
6	DLNR to PGV Permit to Modify Kapoho State Well 1-A	6/16/89
	PGV Application for UIC	6/26/89
7	Ormat to DLNR Application for Permit to Drill KS-3	6/30/89
	DOH ATC (Power Plant)	9/25/89
	DOH ATC (Well Field)	9/25/89
	GRP Approval With Conditions	10/3/89
	DOH Request for DLNR Review of UIC Application	11/30/89
	DLNR Review of PGV UIC Application	1/9/90
	DOH Hearing Officer's Report	2/6/90
	DOH ATC Permit Approval with Conditions	2/6/90
	DOH ATC Permit Approval with Conditions	2/6/90

Hawaii County to DLNR re Technical Task Force for Monitoring	2/22/90
DOH UIC Permit Approval with Conditions	3/16/90
DOH Modification to ATC (Plant)	3/16/90
DOH Modification to ATC (Well Field)	3/16/90
DLNR to Hawaii County Supporting Monitoring Program	3/22/90
DOH to PGV for Modification to ATC Permit	4/18/90
Memorandum Harry Kim to Duane Kanuha re Emergency Response Plan	4/20/90
DLNR Historic Sites to Duane Kanuha re GRP Archaeology Report	4/24/90
DOH to PGV Approving Notification of Proposed Site for First Well	5/17/90
DOH to Harry Kim Review of Emergency Response Plan	6/7/90
DOH to U.S. DOD Review of Emergency Response Plan	6/8/90
PGV to DLNR to Submit Current Plans for PGV Project	9/13/90
PGV to DLNR to Request Extension for Well No. 2883-07	9/14/90
PGV to DLNR to Inform of Approval of Emergency Response Plan	9/14/90
PGV to DLNR to Inform of KS-4 to Start Drilling 9/28/90	9/14/90
Kanuha to DLNR Acknowledging Receipt of $250,000	9/27/90
DLNR to Kanuha to Clarify Wording re Asset Fund	10/19/90
DLNR to Kanuha Conveying Check for $250,000 for Asset Fund	10/21/90
DLNR to PGV to Acknowledge Receipt of Plans	10/25/90
Kanuha to DLNR Correcting Wording on Asset Fund	11/1/90
DLNR to Luebben re EIS Not Being Required	11/2/90
DLNR to PGV re Extension for Well	11/7/90
PGV to DLNR re Clarifications	11/17/90

PGV to DLNR re Proposed Changes to Plan of Operations	11/7/90
DLNR to PGV Approving Plan of Operations Changes	12/4/90

JOHN WAIHEE
GOVERNOR OF HAWAII

STATE OF HAWAII
DEPARTMENT OF LAND AND NATURAL RESOURCES
COMMISSION ON WATER RESOURCE MANAGEMENT
P. O. BOX 621
HONOLULU, HAWAII 96809

M
RO
RICH
GUY K.

MANABU TAGOMORI
DEPUTY

REF:WRM-BM

DEC 4 1990

Mr. William J. Teplow
Field Manager
Puna Geothermal Venture Construction
P.O. Box 1337
Hilo, Hawaii 96721-1337

Dear Mr. Teplow:

Thank you for your letter of November 7, 1990 advising the Department of Land and Natural Resources of proposed changes to your Plan of Operations for the Puna Geothermal Venture Project.

The Department, in reviewing your proposed amendments, has no objections to the revised drilling sequence or to the renumbering of the planned wells, and hereby approves your amended Plan of Operations.

Should you have any questions, please contact Manabu Tagomori, Deputy Director, at 548-7533.

Very truly yours,

WILLIAM W. PATY

ORMAT®

November 17, 1990

Mr. Dean Nakano
Department of Land and Natural Resources
P.O. Box 621
Honolulu, HI 96809

Re: Injection well permitting.

Dear Mr. Nakano:

This letter shall serve to confirm the following points regarding injection well permitting for the Puna Geothermal Venture (PGV) that you made to me in our phone conversation of November 16, 1990. The purpose of my inquiry to you was to clarify permitting procedures for the injection wells proposed for the project. The clarifications which you provided are as follows:

1. The Department of Land and Natural Resources (DLNR) is not involved in the permitting for injections wells that are designed and drilled exclusively for injection. The only permit required for drilling of an injection is that issued by the Department of Health (DOH) as part of the Underground Injection Control (UIC) permitting process.

2. In the event that existing wells or wells drilled for production or exploration purposes are to be converted into injection wells, then a DLNR permit will be required in addition to the UIC permit from DOH.

3. PGV shall notify DLNR prior to commencement of injection well drilling.

As per your request, I am enclosing the drilling program for KS-7, which is the first injection well to be drilled.

Thank you for your assistance in this matter.

Sincerely,
PUNA GEOTHERMAL VENTURE

William J. Teplow
Field Manager

cc: N. Clark
C. Iha

PUNA GEOTHERMAL VENTURE CONSTRUCTION

P.O. Box 1337 • Hilo, Hawaii 96721-1337 • Telephone (808) 961-2786 • Facsimile (808) 935-5562

JOHN WAIHEE
GOVERNOR OF HAWAII

STATE OF HAWAII
DEPARTMENT OF LAND AND NATURAL RESOURCES
COMMISSION ON WATER RESOURCE MANAGEMENT
P. O. BOX 621
HONOLULU, HAWAII 96809

REF:WRM-LN

NOV -7 1990

Mr. William F. Teplow
Field Manager
Puna Geothermal Venture Construction
P.O. Box 1337
Hilo, HI 96721-1337

Dear Mr. Teplow:

<u>Extension for PGV Well 2883-07</u>

We acknowledge receipt of your letter requesting a six-month extension of the start-of-construction date for the subject well.

By this letter, your request is approved to extend the start-date from October 2, 1990 to April 2, 1991. All other conditions of the permit remain in effect.

Very truly yours,

/s/ WWP

WILLIAM W. PATY

RECEIVED

90 NOV 9 AM 8 02

DIV. OF WATER & LAND DEVELOPMENT

November 7, 1990

Mr. Manuba Tagomori
Deputy Director
Department of Land and Natural Resources
P.O. Box 621
Honolulu, HI 96809

Re: Proposed changes to Plan of Operation, Puna Geothermal Venture, and notification of bottom hole location.

Dear Mr. Tagomori:

Pursuant to your letter of October 25, 1990, Puna Geothermal Venture (PGV) is hereby respectfully submitting for approval from your office changes in the sequence of production and injection well drilling as proposed in the Plan of Operation. These changes are summarized in Table 1 below. In addition we have made changes in the designation of the wells. These changes are also shown in Table 1. The attached map shows the location and new well names for the wells proposed in the Plan of Operation. Well pad locations, designations, and the number of wells to be drilled remain unchanged from those proposed in the Plan of Operation.

DRILLING SEQUENCE

The revised well drilling sequence and well designations are shown in the following table:

TABLE 1

DRILLING SEQUENCE	NEW WELL NUMBER	PREVIOUS WELL NO. P of O,3/89	WELL PAD	WELL TYPE
1	KS-3	E-1	E	PRODUCTION
2	KS-7	F-1	F	INJECTION
3	KS-1A REWORK	A-2	A	PRODUCTION REWORK
4	KS-4	E-2	E	PRODUCTION
5	KS-5	E-3	E	PRODUCTION
6	KS-6	E-4	E	PRODUCTION
7	KS-9	A-3	A	PRODUCTION
8	KS-10	A-4	A	PRODCUTION
9	KS-11	A-5	A	PRODUCTION
10	KS-8	F-2	F	INJECTION
11	KS-12	B-2	B	PRODUCTION
12	KS-13	B-3	B	PRODUCTION

The above drilling sequence has been revised in order to advance to the earliest possible date the placement in service of the first increments of power plant capacity. This is accomplished by drilling the injection well KS-7 immediately after completion of the first production well, KS-3.

BOTTOM HOLE LOCATION

The proposed bottom hole location for KS-3, the first production well to be drilled, is as follows:

Horizontal deviation: 830 feet.

Bearing: N 21° E.

True vertical depth: 7400 feet from surface.

The proposed bottom hole location for KS-7, the first injection well to be drilled, is as follows:

Horizontal deviation: 647 feet.

Bearing: S 37° E.

True vertical depth: 5000 feet from surface.

A plan view of the well courses is shown in Figure 1 attached.

If you have any questions or comments regarding the above request for changes in the Plan of Operation, please give me a call.

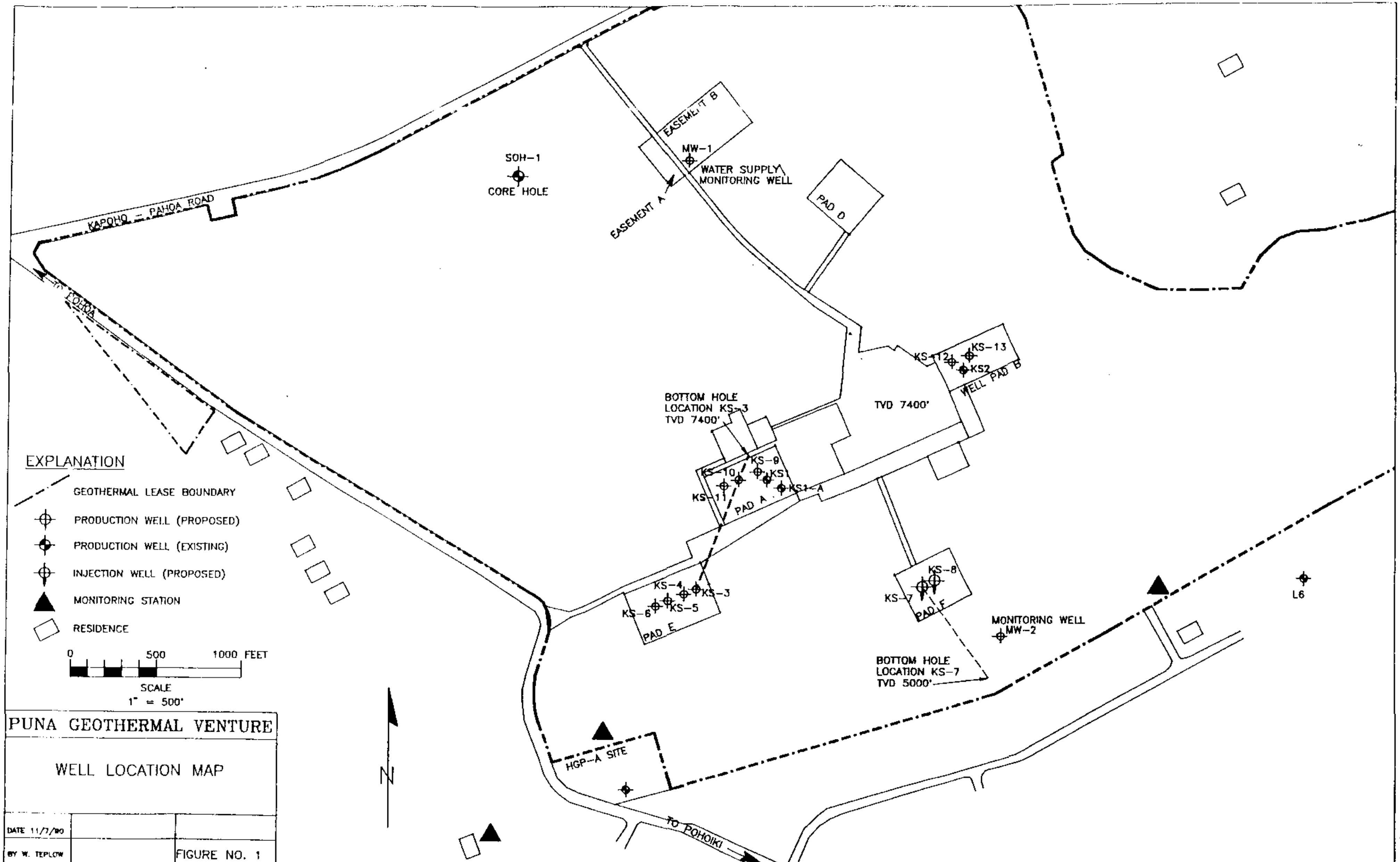
Sincerely,
PUNA GEOTHERMAL VENTURE

William J. Teplow

William J. Teplow
Field Manager

cc: N. Clark
M. Richard
T. Crowson

attachment: Figure 1



PUNA GEOTHERMAL VENTURE

WELL LOCATION MAP

FIGURE NO. 1

STATE OF HAWAII
DEPARTMENT OF LAND AND NATURAL RESOURCES
P. O. BOX 621
HONOLULU, HAWAII 96809

DEPUTIES
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MANABU TAGOMORI
RUSSELL N. FUKUMOTO

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CONSERVATION AND RESOURCES ENFORCEMENT
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LAND MANAGEMENT
STATE PARKS
WATER AND LAND DEVELOPMENT

NOV -2 1990

REF:WRM-MH

Mr. Thomas E. Luebben, Esq.
809 Copper, NW, Suite 200
Albuquerque, New Mexico 87102

Dear Mr. Luebben:

This is in response to your May 11 and July 10, 1990 inquiries as to whether PGV or the State must prepare an environmental assessment under HRS, Chapter 343 regarding Condition No. 51 of the Hawaii County Geothermal Resource Permit (GRP 87-1) issued to Puna Geothermal Venture.

The Department of the Attorney General has reviewed the legal issues raised in your letters and has advised our department that:

1) The situations described in HRS, Section 343-5(a) (2) through (a) (8) do not apply to the Puna Geothermal Venture permit; and

2) Neither PGV nor the State "proposes" any "action" for the use of state or county funds within the meaning of Sections 343-2 or 343-5(a) (1), therefore, neither PGV nor the State must prepare an environmental assessment under HRS 343-5(a)(1).

In summary, neither Puna Geothermal Venture nor the State of Hawaii is required to produce an environmental assessment under Chapter 343, HRS, relative to the Geothermal Asset Fund established in Condition No. 51 of Geothermal Resource Permit GRP 87-1.

Should you have any questions, please contact Mr. Manabu Tagomori, Deputy Director, at (808) 548-7533.

Very truly yours,

/s/ WWP

WILLIAM W. PATY

JOHN WAIHEE
GOVERNOR OF HAWAII

WILLIAM W. PATY, CHAIRPERSON
BOARD OF LAND AND NATURAL RESOURCES

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STATE OF HAWAII
DEPARTMENT OF LAND AND NATURAL RESOURCES
P. O. BOX 621
HONOLULU, HAWAII 96809

OCT 25 1990

REF:WRM-MH

Mr. Norman J. Clark
Project Manager
Puna Geothermal Venture Construction
P.O. Box 1337
Hilo, Hawaii 96721-1337

Dear Mr. Clark:

The Department of Land and Natural Resources has received your construction plans for the Puna Geothermal Venture 25 MW Power Plant Project. We have reviewed the drawings and have no objections to your proposed plans.

We would appreciate your keeping us informed of any proposed revisions to your construction plans. Also, please be advised that if you contemplate any amendments to your Plan of Operations (approved by the Board of Land and Natural Resources on 3/10/89), the Chairperson's approval must be obtained in writing prior to the execution of any such changes.

Should you have any questions, please contact Manabu Tagomori, Deputy Director, at 548-7533.

Very truly yours,

WWPaty

WILLIAM W. PATY

WSM

5E

LARRY S. TANIMOTO
Mayor

Duane Kanuha
Director

William L. Moore
Deputy Director

Planning Department

25 Aupuni Street, Rm. 109 • Hilo, Hawaii 96720 • (808) 961-8288

RECEIVED
90 NOV 8 P 1:41

DIV. OF WATER &
LAND DEVELOPMENT

November 1, 1990

Mr. William W. Paty, Chairperson
Board of Land & Natural Resources
P. O. Box 621
Honolulu, HI 96809

Dear Mr. Paty: Bill

Thanks for your letter of clarification dated October 19, 1990.

We stand corrected in our acknowledgment of September 27, 1990; the proper statement should have been:

"... net revenues derived from the resources generated by by HGP-A well, or a similar amount from other State funding sources ..." (emphasis added)

Our apologies for this typo. We are clearly aware that the State's contribution was never intended to be the source of HGP-A revenues and other State funding sources.

Sincerely,

DUANE KANUHA
Planning Director

DK:aeb

cc: Planning Commission

JOHN WAIHEE
GOVERNOR OF HAWAII

WILLIAM W. PATY, CHAIRPERSON
BOARD OF LAND AND NATURAL RESOURCES

DEPUTIES
KEITH W. AHUE
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STATE OF HAWAII
DEPARTMENT OF LAND AND NATURAL RESOURCES
P. O. BOX 621
HONOLULU, HAWAII 96809

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LAND MANAGEMENT
STATE PARKS
WATER AND LAND DEVELOPMENT

OCT 19 1990

REF:WRM-MH

Mr. Duane Kanuha, Director
Planning Department
County of Hawaii
25 Aupuni Street, Room 109
Hilo, Hawaii 96720

Dear Mr. Kanuha:

Thank you for your letter of September 27, 1990 acknowledging the receipt of our check for $250,000, submitted in compliance with Condition No. 51 of the Geothermal Resource Permit issued to Puna Geothermal Venture.

In your letter, reference was made to Condition No. 51, which we quote as follows:

"The State's initial annual contribution to the Geothermal Asset Fund shall be the net revenues derived from the resources generated by the HGP-A Well, <u>and</u> a similar amount from other State funding sources less any allocation entitled to the Office of Hawaiian Affairs and operations and maintenance costs." (emphasis added)

However, if you will review page 20, item 51 of your GRP-87-1, you will find that the use of the word <u>and</u> is incorrect and section referenced in your letter should more properly have read as follows:

"....net revenues derived from the resources generated by the HGP-A well, <u>or</u> a similar amount from other State funding sources...." (emphasis added)

While the use of the word "and" may have been a typographical error, it should be made very clear that the State's contribution shall be based on either net revenues from HGP-A or other appropriate State funding sources less any allocations, and not the sum total of both, as inferred in your letter.

Should you have any questions concerning the above, please do not hesitate to call me.

Very truly yours,

Bill

WILLIAM W. PATY

WRM!

1781

LARRY S. TANIMOTO
Mayor

Duane Kanuha
Director

William L. Moore
Deputy Director

Planning Department

25 Aupuni Street, Rm. 109 • Hilo, Hawaii 96720 • (808) 961-8288

September 27, 1990

Mr. William W. Paty, Director
Dept. of Land & Natural Resources
P. O. Box 621
Honolulu, HI 96809

Dear Mr. Paty:

This is to acknowledge receipt of the check for $250,000 towards a Geothermal Asset Fund for the purpose of geothermal impact mitigation efforts within the Puna District.

This payment fulfills the State's obligation for its initial annual contribution towards the Geothermal Asset Fund in accordance with Condition No. 51 of Geothermal Resource Permit No. 2.

For your information, Condition 51 states in part that:

> The State's initial <u>annual</u> contribution to the Geothermal Asset Fund shall be the net revenues derived from the resources generated by the HGP-A Well, and a similar amount from other State funding sources less any allocation entitled to the Office of Hawaiian Affairs and operations and maintenance costs. (emphasis added)

Please feel free to call me if you have any questions on the above.

Sincerely,

DUANE KANUHA
Planning Director

WLM:aeb

cc: Planning Commission

JOHN WAIHEE
GOVERNOR OF HAWAII

WILLIAM W. PATY, CHAIRPERSON
BOARD OF LAND AND NATURAL RESOURCES

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STATE OF HAWAII
DEPARTMENT OF LAND AND NATURAL RESOURCES
P. O. BOX 621
HONOLULU, HAWAII 96809

SEP 21 1990

REF:WRM-MH

Mr. Duane Kanuha
Director
Planning Department
County of Hawaii
25 Aupuni Street
Hilo, Hawaii 96720

Dear Mr. Kanuha: Duane

Enclosed is a check for $250,000 to fulfill the State's obligation relative to Condition 51 of the Geothermal Resource Permit (GRP 87-1) issued to Puna Geothermal Venture.

My understanding is that with the $250,000 authorized by the Legislative being deposited in Hawaii County's asset fund account condition 51 has been met.

Sincerely,

Bill

WILLIAM W. PATY

Encl.

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90 SEP 28 P12:10

DIV. OF WATER & LAND DEVELOPMENT

September 14, 1990

Department of Land and Natural Resources
Division of Land Management
P.O. Box 621
Honolulu HI 96709

Dear Sir/Madam:

This notification is to inform you of the approval of the Emergency Response Plan by the Hawaii County Civil Defense Agency. A copy of that plan is available for your review at each of the following locations:

Department of Business, Economic Development, and Tourism
Energy Extension Office
99 Aupuni Street
Room #214
Hilo, HI 96720

Hawaii County Planning Department
25 Aupuni Street
Hilo, HI 96720

Hawaii County Civil Defense Agency
820 Ululani Street
Hilo, HI 96720

Also, be advised that drilling activities for well KS-4 shall commence on September 28, 1990.

Respectfully,

Norman J. Clark

Norman J. Clark
Project Manager

NJC/sdb

PUNA GEOTHERMAL VENTURE CONSTRUCTION
P.O. Box 1337 Hilo, Hawaii 96721-1337
~~99 Aupuni Street #114~~ • ~~Hilo, Hawaii 96720~~ • Telephone (808) 961-2786 • Facsimile (808) 935-5562

Wam

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90 SEP 18 P2:59

DEPT. OF LAND & NATURAL RESOURCES STATE OF HAWAII

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90 SEP 25 P3:36

DIV. OF WATER & LAND DEVELOPMENT

September 14, 1990

William Paty
Chairman
Board of Land & Natural Resources
Kalanimoku Bldg. #130
1151 Punchbowl Street
Honolulu, HI 96813

Subject: Puna Geothermal Venture
Extension for Well No. 2883-07

Dear Mr. Paty,

Puna Geothermal Venture respectfully requests a six month extension to construct Observation Well No. 2883-07. The permit for the well was approved by the Commission on Water Resource Management on April 2, 1990 and the six month commencement period will close on October 2, 1990. We have been unable to proceed with construction because of delays with the project's permitting process, most notably the signing of the Emergency Response Plan by the Civil Defense Director. The grubbing permit required for drill pad preparation was issued on September 7, 1990. It does not appear that we will be able to complete site preparation and mobilize the drill rig before the October 2nd deadline. We are therefore requesting a six month extension of the above referenced permit.

Should you have any questions or require any additional information, please contact me at our Hilo office at 961-2786.

Thank you for your consideration in this matter.

Sincerely,

William F. Teplow
Field Manager

WT/sdb

PUNA GEOTHERMAL VENTURE CONSTRUCTION
P.O. Box 1337 Hilo, Hawaii 96721-1337

Cron

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90 SEP 17 A 8:08

DEPT. OF LAND & NATURAL RESOURCES STATE OF HAWAII

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90 SEP 18 A 8:38

DIV. OF WATER & LAND DEVELOPMENT

September 13, 1990

State of Hawaii
Department of Land & Natural Resources
P.O. Box 621
Honolulu, HI 96709

Attn: Mr. William Paty, Chairman

Re: Geothermal Resources Mining Lease No. R-2
Puna Geothermal Venture

Dear Sir,

Attached herein and as detailed by the attachments, you will find the current set of plans as submitted to Hawaii County in regard to our project plan approval. These drawings are issued in an information only format and if revisions occur, we will forward these to your office.

If you have any questions or problems, please do not hesitate to contact me.

Respectfully,

Norman J. Clark

Norman J. Clark
Project Manager

NJC/sdb
Attachments
cc: MAR

PUNA GEOTHERMAL VENTURE CONSTRUCTION

99 Aupuni Street #114 • Hilo, Hawaii 96720 • Telephone (808) 961-2786 • Facsimile (808) 935-5562

PUNA GEOTHERMAL VENTURE - DRAWINGS LIST 09/11/90

DRAWING NO.	TITLE	LAST REV	LAST REV DATE
89041-C-1	OVERALL SITE PLAN, NOTES, RD INTERSECTION	2	NOV/01/89
89041-C-3	SITE PLAN/UTILITY PLAN	3	JUL/31/90
89041-C-4	SITE PLAN	2	MAR/14/90
89041-C-5	GRADING PLAN - POWER PLANT	4	SEP/07/90
89041-C-7	CHAIN LK FENCE & GATE, DRYWELL CVR & CESSPOOL DET	--	---
89042-G-1	GENERAL LOC & ELEV - MAJOR EQUIPT & STRUCTURES	1	SEP/06/90
8940-00-E-2	OVERALL SITE - CABLING & GROUNDING PLAN	1	SEP/08/90
8940-00-E-13	PLANT SITE - LTG, RECP & SIGNALING PLAN	0	MAY/14/90
8940-00-E-30	TYP. WELLPAD - PLAN	1	---
8940-00-E-31	INJECTION WELLPAD - PLAN	--	---
8940-00-E-32	WELLPAD - O.L. DIAG, DETS, PNL SCHS & CALCS	0	MAY/14/90
8940-00-E-33	LIGHTING DETAILS	0	MAY/14/90
7.799.50.015.0	PIPING GATHERING SYSTEM	0	---
033.2900-L1	SITE ANALYSIS	--	MAR/13/90
033.2900-L2	LINE OF SIGHT ANALYSIS	--	MAR/13/90
033.2900-L3	SITE REVEGETATION/RECLAIM PLAN	--	MAR/13/90
033.2900-L4	POWER PLANT & TYPICAL WELL PLANTING PLAN	--	MAR/13/90
033.2900-L5	LINE OF SIGHT ANALYSIS	--	APR/16/90
033.2900-L6	LINE OF SIGHT ANALYSIS	--	APR/27/90
FP-1	FIRE PROTECTION SITE PLAN	--	MAR/08/90
FP-2	FIRE PUMP LAYOUT	--	MAR/08/90
FP-3	SPRINKLER PIPING PLANS	--	MAR/08/90

WRM

13'1

JOHN WAIHEE
GOVERNOR OF HAWAII

JOHN C. LEWIN, M.D.
DIRECTOR OF HEALTH

RECEIVED

90 JUN 15 P12:23

STATE OF HAWAII
DEPARTMENT OF HEALTH
P. O. BOX 3378
HONOLULU, HAWAII 96801

& NATURAL RESOURCES
STATE OF HAWAII

In reply, please refer to:
File:

June 8, 1990

Major General Alexis T. Lum
Office of the Adjutant General and
Director of Civil Defense
Department of Defense
3949 Diamond Head Road
Honolulu, Hawaii 96816

Dear Major General Lum:

The attached letter to the Big-Island Civil Defense Coordinator is written to offer assistance in developing logical and appropriate plans for emergency response with respect to geothermal development on the Big-Island.

We hope these comments will be helpful in responding to the plans in this regard in a timely manner.

Please don't hesitate to contact my office if the Department can further assist in this matter.

Sincerely yours,

JOHN C. LEWIN, M.D.
Director of Health

c: Governor John Waihee
Sus Ono

bc: Dr. Joshua Agsalud
Charles Freedman
The Honorable Roger Ulveling
✓The Honorable William W. Paty
Dr. Bruce Anderson
Mark Ingoglia

JOHN WAIHEE
GOVERNOR OF HAWAII

JOHN C. LEWIN, M.D.
DIRECTOR OF HEALTH

STATE OF HAWAII
DEPARTMENT OF HEALTH
P. O. BOX 3378
HONOLULU, HAWAII 96801

In reply, please refer to:
HEER OFFICE

7 June 1990

Mr. Harry Kim, Chairman
Hawaii Local Emergency Planning Committee
34-A Rainbow Drive
Hilo, Hawaii 96720

Subject: Review of the Puna Geothermal Venture 25 MW Power Project Emergency Response Plan

Dear Mr. Kim:

Thank you for the opportunity to review the Puna Geothermal Venture 25 MW Power Project Emergency Response Plan. The plan includes a reasonable review of the potential hazards that maybe posed by the project. The following comments and recommendations are offered to improve and enhance the document. If these comments and recommendations are fully implemented on a consistent basis while the facility is constructed and operated, public and private interests should be prepared for the emergencies that may arise or affect the proposed development.

<u>Notification</u>

The 24 hour notification number for the Department of Health Clean Air Branch for emergency response is 247-2191, and should be included in Table 2-1, page 8. Department of Land and Natural Resources should replace Lands and Natural Resources. The National Response Center in Washington D.C., phone number (800) 424-8802, should be included for a federal response. Due to mining exemptions we are unclear if isopentane releases are required to be reported under the federal Superfund law. This should be determined by the applicant and reportable quantities listed at appropriate locations in the plan. If regulated, follow-up written release reporting under Section 304 of Title III is required. If the mining exemption does apply, we recommend requiring notification of releases similar to the federal Superfund in the plan.

Emergency and Nuisance Situations

Under Section 3.1 Emergency conditions, page 11, you have proposed that an emergency condition exists when H_2S levels reach 20 parts per million (ppm) at the property boundary, however this action level is inconsistent with the levels the state is proposing.

The Department of Health has proposed action levels for H_2S including "alert", " warning", and "emergency" levels. The rationale for the establishment of these action levels and actions called for is as follows:

1. The Alert level is that concentration of (H_2S) at which short-term health effects can be expected to occur.

Recommendation: 0.10 ppm (100 parts per billion) H_2S (over a one-hour averaging period).

Rational: In light of the available literature, a maximum ambient standard of H_2S of 0.10 ppm is safe from a toxic effect standpoint. It follows that deleterious physiologic health effects may begin to occur at levels above 0.10 ppm among those most susceptible. This number was based on the lowest level well-documented to be associated with human eye irritation, a short -term effect, with a one hundred-fold safety factor included.

2. The warning level indicates that air quality is continuing to deteriorate and that additional abatement actions are necessary.

Recommendation: 1.00 ppm H_2S (over a one-hour averaging period).
Rational: This level is between that at which short-term health effects can be expected to occur (0.10 ppm H_2S) and that at which a substantial endangerment to human health can be expected (10.0 ppm H_2S).

3. The Emergency level is that level at which a substantial endangerment to human health can be expected.

Recommendation: 10.0 ppm H_2S (over a one-hour averaging period).
Rational: Eye irritation and decreased corneal reflex have been well documented to be associated with levels of exposure above 10.0 ppm H_2S. Lung damage may also be occurring at this level but is difficult to detect.

The U.S. National Institute for Occupational Safety and Health maintains an allowable ceiling concentration of 10.0 ppm for 10-minutes is safe. It may be inferred from this that any exposure above 10.0 ppm is unsafe. Immediate evacuation of a facility is required if the concentration of H_2S at any time exceeds 47 ppm O.S.H.A.

The American Conference of Governmental Industrial Hygienists also recommends the "Threshold Limit Value" to be 10 ppm H_2S. This is the concentration of H_2S to which it is believed nearly all humans may be exposed in the working environment day after day (over an 8-hour exposure period) without adverse health effects. Those who are hypersensitive to H_2S, including the aged, infants, individuals with predisposing eye and respiratory problems, and those who are anemic, may be adversely affected at lower levels.

Thus, in reviewing the literature, it may be concluded that levels of exposure above 10.0 ppm pose a substantial endangerment to human health. The plan should discuss fully the use of these levels and integrate them into the planning and response mechanism of the plan.

Response Facilities

All response and safety facilities, as well as general grading in the area should be constructed to ensure that they will not serve to capture H_2S in a depression and thereby cause a hazard. Table 4-1 indicates that there are 12 "air packs". The type of self contained breathing apparatus and their air capacity should be included. Air monitoring devices should also be listed. Portable real time monitors should be available along with the "air packs" and should be described.

PGV Personnel Training and Emergency Drill

As cited on page 27, OSHA training will be provided. This should be described, and if possible a draft training plan should be attached to the emergency response plan as an appendix or addendum. A description of a "general drill" should be included to provide insight into what such an exercise will provide and it's value.

Uncontrolled Steam Releases from the Reservoir

A worst case well blow out has been modeled, "...under any weather conditions typical of the site vicinity. " This term should be defined and related to planning for "untypical" weather conditions; a reasonable "worst case scenario" should be included in the risk analysis and should include, but not be limited to methods described in the following guidance:

U.S. Environmental Protection Agency, Federal Emergency Management Agency, U.S. Department of Transportation (1987) Technical Guidance for Hazards Analysis: Emergency Planning for Extremely Hazardous Substances.

Federal Emergency Management Agency, U.S. Department of Transportation, U.S. Environmental Protection Agency (1987) Handbook of Chemical Hazard Analysis Procedures.

It is recommended that upon the occurrence of an uncontrolled release, the Hawaii Civil Defense Agency and the Department of Health should be notified immediately and periodically updated. Other reporting requirements are specified in the permits issued by the Department of Health.

We look forward to continued cooperation to improve Hawaii's capability to respond to chemical emergencies. If you have any questions regarding this review, please contact Bruce Anderson, Ph.D., Deputy Director for Environmental Health at 548-4139.

Sincerely,

JOHN C. LEWIN, M.D., Chairman,
Hawaii State Emergency Response
Commission and Director of Health

cc: Samuel Ruben, M.D., District Health Administrative Officer
Hawaii District Health Office.

COPY

May 17, 1990

90-A236
File #833

Mr. Maurice A. Richard
Regional Development Manager
Puna Geothermal Venture
101 Aupuni Street, Suite 1014-B
Hilo, Hawaii 96720

Dear Mr. Richard:

Subject: Authority to Construct (ATC) No. A-833-795
Fourteen (14) Geothermal Exploratory/Developmental Wells

The Department of Health acknowledges receipt and has completed its review of your written notification, including the location drawing and information on the previously constructed wells. The Department hereby approves the notification of the proposed site for the construction of the first geothermal well.

It should be noted that in accordance with the Special Conditions of ATC No. A-833-795, the construction of any geothermal well is not authorized, until such time the air quality and meteorological monitoring stations are fully operational. Please inform the Department in writing upon initiating operations of the monitoring stations.

If you have any questions, please call Mr. Nolan Hirai of the Clean Air Branch at 543-8200.

Sincerely,

Bruce S. Anderson

BRUCE S. ANDERSON, Ph.D.
Deputy Director for
Environmental Health

NH/sk
cc: DHSA, Hawaii
Rodney Nakano, Hawaii County Planning Department
Manabu Tagomori, Department of Land & Natural Resources

April 24, 1990

Mr. Duane Kanuha
Planning Director
County of Hawaii
Planning Department
25 Aupuni Street, Rm. 109
Hilo, Hawaii 96720

Dear Mr. Kanuha:

SUBJECT: County of Hawaii, Geothermal Resources Permit No. 2
Puna Geothermal Venture
Kapoho, Puna, Hawaii
TMK: 1-4-1: part 2, 3, part 19, 58

Thank you for your letter of March 23, 1990, which enclosed the archaeological report for Condition 30 of this permit (Kennedy 1990. Archaeological Walk-Through Reconnaissance Survey for the Proposed Puna Geothermal Venture Project Site. Archaeological Consultants of Hawaii.).

We agree with the report's findings that no historic sites are present on the surface of the project area. This finding had been established in a previous historic preservation review for the project.

Given the recent findings related to the True/Mid-Pacific Geothermal area -- findings of subsurface lava caves with historic remains in them -- we believe that it would be useful for this possible presence of such caves to be considered in the archaeological survey of this project. This could be done in two ways. One, the archaeological consultant could evaluate the possiblity of caves being present through information obtained on lava terrain present, information from geologists, and information from local residents on known caves that might pass under the project. Then, if caves are unlikely to be present, this concern is eliminated. If caves were likely to be present, then planning to deal with such a situation could be done. Two, an archaeologist could be kept on call in case a tube cave was encountered, and then could check any discovered caves for cultural remains and if such remains were present could then consult with your department and our office for mitigation measures, if needed. The first approach would be best, since it would obtain an evaluation prior to subsurface drilling work.

Sincerely,

/s/ DON HIBBARD

DON HIBBARD, Director
Historic Preservation Program

RC:al 4/24/90 APR 24 1990

Civil Defense Agency

Larry S. Tanimot
Mayor

34-A Rainbow Drive • Hilo, Hawaii 96720 • (808) 935-0031 • Fax (808) 935-6460

doc04780

TO: Duane Kanuha, Planning Director

FROM: Harry Kim, Civil Defense Administrator HK

DATE: April 20, 1990

SUBJECT: Emergency Response Plan--Puna Geothermal Venture

I have continued to work with Puna Geothermal Venture's staff to complete an acceptable Emergency Response Plan for their planned Geothermal Project at Kapoho. We are presently trying to resolve some details, however, the Civil Defense Agency's involvement at the Kalapana lava front has made coordinating our efforts more difficult.

It is my understanding that in accordance with Condition No. 26 of the Planning Commission's Geothermal Resource Permit, a final plan of action to deal with emergency situations must be approved prior to commencing any activity approved under this permit. It is my understanding that environmental monitoring equipment including the meteorological tower, the air quality and noise monitoring stations have not been installed and their installation has been delayed pending approval of the Emergency Response Plan.

It is also my understanding that this Emergency Response Plan is intended to be a living document subject to revisions and clarifications as needed and to provide a working document appropriate to respond to future natural or man-made emergencies.

In view of this, the installation of environmental monitoring equipment should be allowed to proceed without further delays caused by this office. Any other activity must await approval of the Emergency Response Plan which will be reviewed as soon as possible.

dy

JOHN WAIHEE
GOVERNOR OF HAWAII

STATE OF HAWAII
DEPARTMENT OF HEALTH
P. O. BOX 3378
HONOLULU, HAWAII 96801

JOHN C. LEWIN, M.D.
DIRECTOR OF HEALTH

In reply, please refer to:
EMD-CAB

April 18, 1990

90-A165
File Nos. 833 and 834

Mr. Manabu Tagomori
Water & Land Development Division
Department of Land & Natural Resources
1151 Punchbowl Street, Room 227
Honolulu, HI 96813

Dear Mr. Tagomori:

Subject: Modification to Authority to Construct Permits
Regulating the Emissions of Air Pollutants
Puna Geothermal Venture
25 MW Geothermal Power Plant and Wellfield

On March 16, 1990, the Department of Health modified the Authority to Construct air permits, Nos. A-833-795 and A-834-796, which were issued to Puna Geothermal Venture on February 6, 1990 for the fourteen (14) geothermal wells and the 25 MW geothermal power plant. The special conditions to the corresponding air permits were modified for clarification purposes and to minimize any misinterpretations.

For your information, a copy of the modifications to the air permits is enclosed.

Your continued interest is welcomed and appreciated.

Sincerely,

Bruce S. Anderson

BRUCE S. ANDERSON, Ph.D.
Deputy Director for
Environmental Health

WN/sk
Enclosures
cc: DHSA, Hawaii

CERTIFIED MAIL
RETURN RECEIPT REQUESTED

March 16, 1990

90-A99
File #833

Mr. Maurice A. Richard
Regional Development Manager
Puna Geothermal Venture
101 Aupuni Street, Suite 1014-B
Hilo, Hawaii 96720

Dear Mr. Richard:

Subject: Modification to Authority to Construct No. A-833-795
Fourteen (14) Geothermal Exploratory/Development Wells
Located at TMK: 1-4-01:2, 1-4-01:3, 1-4-01:58 and 1-4-01:19,
Kilauea Lower East Rift Zone, Puna, Hawaii

Pursuant to Chapter 342B, Hawaii Revised Statutes, and Chapter 11-60, Hawaii Administrative Rules, the Department of Health (DOH) hereby modifies the subject Authority to Construct No. A-833-795.

The following modified special conditions supersede the corresponding special conditions of Attachment II issued with ATC No. A-833-795 dated February 6, 1990:

Special Condition No. 2

This Authority to Construct is for fourteen (14) geothermal exploratory/developmental wells to be drilled in TMK: 1-4-01:2, 1-4-01:3, 1-4-01:58 and 1-4-01:19, Kilauea Lower East Rift Zone, Puna, Hawaii. Written notification must be submitted to and approval obtained from the Department of Health prior to the commencement of construction of each well. The Department of Health shall act on the approval in a timely manner provided all required and requested information have been submitted. Each notification shall include a drawing identifying the well location, the property boundary, access roads approaching and traversing the property, the location of the nearest residence, and the locations of the air quality monitoring stations. The status of all previous constructed wells shall be provided including a clear description of the measures taken to shut-in the well. Additional information may be requested of the permittee.

Special Condition No. 3

The permittee shall obtain a Permit to Operate prior to any well approved under this permit being connected to and becoming a part of a distribution system which supplies geothermal resource to a power plant or facility. Additional permit conditions may be included in the Permit to Operate.

Special Condition No. 5

The permittee shall install, operate, and maintain a minimum of one (1) meteorological and three (3) air quality monitoring stations. The monitoring stations required in any permit for the 25 MW power plant may be used towards fulfilling this requirement.

Prior to the commencement of construction of each of the fourteen (14) wells, the permittee shall submit for the Department of Health's approval the siting of the air quality and meteorological monitoring stations. The air quality and meteorological monitoring stations shall be fully operational prior to the commencement of drilling operations. The permittee shall maintain a file of all measurements, including the monitoring system performance evaluations; calibration checks; and adjustments and maintenance performed on the system or devices. The measured data shall meet U.S. EPA capture requirements and quality assurance guidelines. At a minimum, a quality assurance check shall be conducted on each monitoring station every-other-day.

The air quality monitors shall be equipped with an alarm system or an acceptable equivalent system that will immediately notify the permittee of ambient hydrogen sulfide concentrations in excess of 25 ppb (above background) and 100 ppb (including background) on a one-hour average. The permittee shall immediately notify the Department of Health and the Hilo District Health Office of any exceedance above 25 ppb (above background) and 100 ppb (including background) on a one-hour average.

Two (2) copies of the data file in a format acceptable to the Department of Health shall be submitted on an annual basis. The data file shall be in a format that can be utilized by a personal computer for ready extraction of data. The air quality and meteorological data shall be summarized and submitted monthly in writing to the Department of Health. Additional information on the monitoring stations and on the data collected shall be submitted upon request by the Department of Health.

Special Condition No. 9

Flaring of excess hydrogen sulfide gas from the completed wells is prohibited without the approval of the Department of Health. If flaring of the excess gas is considered necessary, the permittee must submit a written request to the Department of Health which shall include as a minimum the proposed date, time and approximate duration of the flaring episode, the current and expected well head pressure, the estimated hydrogen sulfide concentration in the well gas, the estimated emission rates for hydrogen sulfide and sulfur dioxide, an air quality impact analysis for sulfur dioxide, the probable cause of excess gas buildup, and an assessment of any abatement alternatives.

If a request to flare excess gas is approved as necessary by the Department of Health, the approval may be subject to specified conditions. These conditions may include, but are not limited to, provisions requiring the permittee to install, operate, and maintain sulfur dioxide ambient monitors and to submit to the Department of Health after the flaring event a report on the times flaring actually occurred, the sulfur dioxide emissions determined through either direct or indirect measurements, and any problems encountered during the flaring process.

Special Condition No. 11

The permittee shall have proper safety devices on-site at least three days prior to commencement of drilling operations. A minimum of three breathing apparati shall be available at the site and maintained by a qualified person/contractor. Wind socks shall be placed at two opposite edges of the drill site and on the drill floor. At least one person with certified hydrogen sulfide training to respond to hydrogen sulfide emergency episodes shall be on-site at all times.

Special Condition No. 13

The permittee shall monitor the hydrogen sulfide concentration and emission rate continuously in the steam by use of an electrochemical type sensor and recorder during the flow testing operations. If the abated hydrogen sulfide emission rate increases to five (5.0) pounds per hour or more, the permittee shall cease operations and shut-in the well. The Department of Health shall be so notified and the problem corrected before testing operations can continue.

During periods of well equipment failure or malfunction which result in hydrogen sulfide emissions, the permittee shall apply best available control technology for the air emissions and take immediate steps to correct the condition. The Department of Health shall be immediately notified of the well equipment failure or malfunction. If the well equipment in question cannot be repaired within twenty-four (24) hours of the occurrence or the hydrogen sulfide ambient concentration exceeds the specified limits in Special Condition Nos. 23, 27 and 28, the permittee shall cease operations and shut-in the well in accordance with Special Condition Nos. 23, 27 and 28. Within five (5) days of the occurrence, a report shall be submitted to the Department of Health. The report shall include a description of the equipment failure or malfunction, the date of the initial failure, the estimated resultant emissions, time and duration of the event, and the repairs conducted to restore normal operations. Compliance with this notification provision shall not excuse or otherwise constitute a defense for any violation(s) of this permit, law, rule, or order which results from the well equipment failure or malfunction.

Special Condition No. 17

The permittee shall utilize mud drilling techniques to the extent possible during the well drilling operations. In no case shall air drilling be used in the construction of the geothermal well. The drilling with aerated mud or aerated water may be used in lieu of mud drilling, but should be minimized to the extent practicable. Should any releases of steam occur during the drilling operations, the drilling fluid weight shall be immediately increased to stop the steam flow. In no case shall any inadvertent steam releases result in hydrogen sulfide emissions of five (5.0) pounds per hour or more, or exceed seven (7) minutes in duration in any one hour. If the inadvertent steam releases cannot be controlled by increasing the fluid weight or exceeds seven (7) minutes in duration in any one hour, the permittee shall take immediate action to shut-in the well.

Records of each steam release incident shall be maintained and include as a minimum, date, time and duration of the incident, the estimated resultant emissions, and any corrective measures taken. The records shall be in a permanent form suitable for inspection, shall be made available upon request by the Department of Health, and shall be retained for at least three (3) years following the date of such records.

Special Condition No. 22

Unabated well venting shall be allowed only after the permittee has checked with the National Weather Service and is assured of meteorological conditions appropriate for optimal dispersion and minimal air quality impact. In no case shall the well venting commence if the average wind speed at the well site is less than 4 meters per second (8.9 miles per hour). Prior to well venting, the Department must be informed in writing a minimum of two (2) days prior to commencement and so concur. The public shall be notified a minimum of 24-hours in advance by notices in the newspapers of general circulation in Hawaii County. In addition, the permittee shall make a reasonable effort to notify all residents living within 3,500 feet of the permittee's property boundary a minimum of 24-hours in advance of open venting of each well and pipeline cleanout. In preparation for flow testing, each well shall be allowed to open vent only during the daytime and no more than a total of four (4) hours.

In no case shall any well venting coincide with any pipeline cleanouts, or well flow testing operations, or commence if the power plant emergency steam release facility is being utilized. If emergency steam releases from the power plant occur during the venting of any well, venting of that well shall be terminated as quickly as practical.

Special Condition No. 23

In no case shall the well drilling, flow testing, venting operations, or well equipment failure or malfunction of any of the fourteen (14) geothermal exploratory/developmental wells cause or contribute to an exceedance of the hydrogen sulfide ambient level of 100 ppb (including background) on a one-hour average at or beyond the project boundary. Should any of the approved air quality monitoring stations indicate a hydrogen sulfide ambient concentration greater than 100 ppb (including background) on a one-hour average, the permittee shall immediately notify the Department of Health, ceasing all well drilling with aerated mud or aerated water, well flow testing, and well venting operations, and shutting in those wells experiencing equipment failure or malfunction, which result in emissions of hydrogen sulfide. The affected wellfield construction activities shall be allowed to proceed only after the permittee has satisfactorily demonstrated to the Department of Health that the contributions from the well drilling with aerated mud or aerated water, well flow testing, well venting operations or well equipment repair will not result in or contribute to the exceedance of the hydrogen sulfide ambient concentration of 100 ppb (including background) on a one-hour average.

The permittee shall submit to the Department of Health a written follow-up report within five (5) days of the occurrence. The report shall include the date, time and duration of the exceedance(s), the status of all project operations during the exceedance, the estimated project emissions and any other emission sources that may have contributed to the exceedance, and all corrective measures and actions to reduce project emissions to a minimum. Compliance with this notification provision shall not excuse or otherwise constitute a defense to any violation(s) of this permit or of any law or regulations.

Special Condition No. 27

During those periods of normal power plant and normal wellfield operations, the combined emissions of hydrogen sulfide from the 25 MW geothermal power plant (A-834) and associated wellfield (A-833) shall not cause an increase in the hydrogen sulfide ambient concentration in excess of 5 ppb (above background) on a one-hour average at or beyond the project boundary as monitored at any of the approved air quality monitoring stations and so identified in the monthly monitoring report. As used in this context, a normal power plant operation is a power plant which is operating without any upsets, equipment failure, malfunction or which is otherwise operating normally. A normal wellfield operation is a wellfield in which no well drilling, flow testing, or venting activities are occurring and where the completed wells are not experiencing any equipment failure or malfunction and are either shut-in, being used as an injection well, or connected to a sound geothermal resource distribution system.

Special Condition No. 28

Excluding periods of well venting and pipeline cleanout, the combined emissions of hydrogen sulfide from the 25 MW geothermal power plant (A-834) and associated wellfield (A-833) shall not cause an increase in the hydrogen sulfide ambient concentration in excess of 25 ppb (above background) on a one-hour average at or beyond the project boundary as monitored at any of the approved air quality monitoring stations and so identified in the monthly monitoring report.

Should any of the approved air quality monitoring stations indicate a hydrogen sulfide ambient concentration greater than 25 ppb (above background) on a one-hour average, the permittee shall immediately notify the Department of Health and the Hilo District Health Office and shall cease all geothermal well drilling with aerated mud or aerated water, well flow testing, and scheduled project maintenance, and shut-in those wells experiencing equipment failure or malfunction, which result in emissions of hydrogen sulfide. The affected well drilling, flow testing, scheduled maintenance, and well equipment repair shall be allowed to proceed only after the permittee has satisfactorily demonstrated to the Department of Health that the hydrogen sulfide emissions from the affected well drilling, flow testing, scheduled maintenance, well equipment or power plant repairs, power plant emergency steam release, or normal power plant operation, whether separately or in any combination, did not or will not cause an increase in the hydrogen sulfide ambient concentration in excess of 25 ppb (above background) on a one-hour average.

The following special condition of Attachment II issued with ATC No. A-833-795 dated February 6, 1990 is hereby deleted:

Special Condition No. 24

The drilling, flow testing, and venting operations of any of the fourteen (14) geothermal exploratory/developmental wells shall not cause or contribute to an exceedance of the hydrogen sulfide ambient level of 100 ppb on a one-hour average at or beyond the project boundary.

All other special conditions of Attachment II (Special Condition Nos. 1, 4, 6, 7, 8, 10, 12, 14, 15, 16, 18, 19, 20, 21, 25 and 26) issued with ATC No. A-833-795 dated February 6, 1990 shall not be affected and shall remain valid.

These modifications shall become final twenty (20) days after receipt, unless before the twenty (20) days expire, Puna Geothermal Venture submits a written request to the Director of Health for a hearing pursuant to Chapters 91 and 342B, Hawaii Revised Statutes. If a hearing is requested, it will be held at a date, time, and place to be specified later and conducted in accordance with Chapter 91, Hawaii Revised Statutes, and the rules of Practice and Procedure of the Department of Health.

Very truly yours,

JOHN C. LEWIN, M.D.
Director of Health

WN/sk
cc: DHSA, Hawaii

COPY FOR YOUR INFORMATION

March 16, 1990
Ramseyer

ATTACHMENT II. SPECIAL CONDITIONS OF AUTHORITY TO CONSTRUCT, NO. A-833-795
APPLICATION NO. A-833
WELLFIELD

In addition to the standard conditions of the Authority to Construct, this permit is subject to the following special conditions:

1. The permit conditions prescribed herein may at any time be revised by the Department of Health to conform to any Federal or State promulgated air quality rules on geothermal facilities.

2. This Authority to Construct is for fourteen (14) geothermal exploratory/developmental wells to be drilled in TMK: 1-4-01:2, 1-4-01:3, 1-4-01:58 and 1-4-01:19, Kilauea Lower East Rift Zone, Puna, Hawaii. Written notification must be submitted to and approval obtained [with minimal delay] from the Department of Health prior to commencement of construction of each well. **The Department of Health shall act on the approval in a timely manner provided all required and requested information have been submitted.** Each notification shall include a drawing identifying the well location, the property boundary, access roads approaching and traversing the property, the location of the nearest residence, and the locations of the air quality monitoring stations. The status of all previous constructed wells shall be provided including a clear description of the measures taken to shut-in the well. Additional information may be requested of the permittee.

3. The [Department of Health shall act on] **permittee shall obtain** a Permit to Operate [Application] prior to any well approved under this permit being connected and becoming a part of a distribution system which supplies geothermal resource to a power plant or facility. Additional permit conditions may be included in the Permit to Operate.

4. No geothermal exploratory/developmental wells shall be located within 600 feet of the property boundary. If any federal, state or county permit or order stipulates a distance greater than 600 feet in which no geothermal wells can be located, the greater distance shall so apply.

5. The permittee shall install, operate, and maintain a minimum of one (1) meteorological and three (3) air quality monitoring stations. The monitoring stations required in any permit for the 25 MW power plant may be used towards fulfilling this requirement.

   Prior to the commencement of construction of each of the fourteen (14) wells, the permittee shall submit for the Department of Health's approval the siting of the air quality and meteorological monitoring stations. The air quality and meteorological monitoring stations shall be fully operational prior to the commencement of drilling operations. The permittee shall maintain a file of all measurements, including the monitoring system performance evaluations; calibration checks; and adjustments and maintenance performed on the system or devices. The measured data shall meet U.S. EPA capture requirements and quality assurance guidelines. At a minimum, a quality assurance check shall be conducted on each monitoring station every-other-day.

   The air quality monitors shall be equipped with an alarm system or an acceptable equivalent system that will immediately notify the permittee of ambient hydrogen sulfide concentrations in excess of 25 ppb **(above background)** and 100 ppb **(including background)** on a one-hour average. The permittee shall immediately notify the Department of Health and the Hilo District Health Office of any exceedance above **25 ppb (above background) and 100 ppb (including background) on a one-hour average.**

Two (2) copies of the data file in a format acceptable to the Department of Health shall be submitted on an annual basis. The data file shall be in a format that can be utilized by a personal computer for ready extraction of data. The air quality and meteorological data shall be summarized and submitted monthly in writing to the Department of Health. Additional information on the monitoring stations and on the data collected shall be submitted upon request by the Department of Health.

6. At the discretion of the Director of Health, the permittee may at any time be required to install, operate, and maintain additional air quality and meteorological monitoring stations, but only after due notice to the permittee on the reasons for the proposed change and providing the permittee an opportunity to respond within seven (7) days.

7. The permittee shall notify the Department of Health in writing at least two (2) working days prior to the commencement, and within two (2) working days after the completion of the aerated mud or aerated water drilling, well venting, and flow testing operations, for each geothermal well.

8. Upon completion of flow testing operations, each geothermal well shall be shut-in or otherwise prevented from discharging to the atmosphere in accordance with appropriate standards of operation and maintenance and at no time be placed on continuous or standby bleed status.

9. [Occasional flaring of excess hydrogen sulfide gas from the completed wells is prohibited unless such flaring is necessary to insure well integrity or safety and is conducted in such a manner that no state or national ambient air quality standards for sulfur dioxide are exceeded. Records shall be maintained on all flaring episodes, and shall include, as a minimum, the date, time and duration of the event, probable causes of the excess gas buildup, and the estimated emissions of sulfur dioxides determined through either direct or indirect measurements. The records shall be in a permanent form suitable for inspection and shall be retained for at least three (3) years following the date of such records. The permittee shall submit a written report monthly to the Department of Health on the flaring episodes which demonstrates compliance with the requirements of this condition. If flaring occurs frequently or routinely, the permittee shall install, operate, and maintain ambient sulfur dioxide monitors at each air quality monitoring station and comply with all recordkeeping requirements in accordance with Special Condition No. 5.]

   Flaring of excess hydrogen sulfide gas from the completed wells is prohibited without the approval of the Department of Health. If flaring of the excess gas is considered necessary, the permittee must submit a written request to the Department of Health which shall include as a minimum the proposed date, time and approximate duration of the flaring episode, the current and expected well head pressure, the estimated hydrogen sulfide concentration in the well gas, the estimated emission rates for hydrogen sulfide and sulfur dioxide, an air quality impact analysis for sulfur dioxide, the probable cause of excess gas buildup, and an assessment of any abatement alternatives.

   If a request to flare excess gas is approved as necessary by the Department of Health, the approval may be subject to specified conditions. These conditions may

include, but are not limited to, provisions requiring the permittee to install, operate, and maintain sulfur dioxide ambient monitors and to submit to the Department of Health after the flaring event a report on the times flaring actually occurred, the sulfur dioxide emissions determined through either direct or indirect measurements, and any problems encountered during the flaring process.

10. All access roads into the property shall be limited to authorized personnel only. Twenty-four hour staffing shall be in place during construction.

11. The permittee shall have proper safety devices on-site at least three days prior to commencement of [air] drilling **operations**. A minimum of three breathing apparati shall be available at the site and maintained by a qualified person/contractor. Wind socks shall be placed at two opposite edges of the drill site and on the drill floor. At least one person with certified hydrogen sulfide training to respond to hydrogen sulfide emergency episodes shall be on-site at all times.

12. Hydrogen sulfide abatement equipment with a minimum of 3,000 gallons of sodium hydroxide shall be on the property prior to the initiation of flow testing operations. Chemical storage tanks shall be maintained with sodium hydroxide at all times with no less than a three-day operating supply.

13. The permittee shall monitor the hydrogen sulfide concentration and emission rate continuously in the steam by use of an electrochemical type sensor and recorder during the flow testing operations. If the abated hydrogen sulfide emission rate increases to five (5.0) pounds per hour or more, the permittee shall cease operations and shut-in the well. The Department of Health shall be so notified and the problem corrected before testing operations can continue.

    During periods of **well** equipment failure or malfunction which result in hydrogen sulfide emissions, the permittee shall apply best available control technology for the air emissions and [shall so notify the Department of Health within one (1) hour of the occurrence. The permittee shall immediately] take **immediate** steps to correct the condition. **The Department of Health shall be immediately notified of the well equipment failure or malfunction.** If [repairs] **the well equipment in question** cannot be [accomplished] **repaired** within twenty-four (24) hours of the occurrence **or the hydrogen sulfide ambient concentration exceeds the specified limits in Special Condition Nos. 23, 27 and 28,** the permittee shall cease operations and shut-in the well **in accordance with Special Condition Nos. 23, 27 and 28.** Within five (5) days of the occurrence, a report shall be submitted to the Department of Health [in accordance with Hawaii Administrative Rules, Section 11-60-14]. **The report shall include a description of the equipment failure or malfunction, the date of the initial failure, the estimated resultant emissions, time and duration of the event, and the repairs conducted to restore normal operations. Compliance with this notification provision shall not excuse or otherwise constitute a defense for any violation(s) of this permit, law, rule, or order which results from the well equipment failure or malfunction.**

14. Wet chemical tests for the determination of the hydrogen sulfide concentrations shall be conducted and recorded on a daily basis during all phases of the flow testing operations.

15. The following data shall be recorded during the flow testing operations:

    a. At least four times per 24-hour period, hydrogen sulfide ppm upstream from the injection system.

b. At least four times per 24-hour period, injection rate of sodium hydroxide.

c. At least four times per 24-hour period, hydrogen sulfide emission rate (lbs/hr) and concentration (ppm) downstream, after chemical injection.

d. Daily, zero and span check of hydrogen sulfide sensor.

e. Weekly, calibration check of hydrogen sulfide sensor.

f. Daily, the quantity of sodium hydroxide remaining in the abatement equipment storage tanks.

Additional entries will be made when significant changes in the resource occurs and when changes are made in injection rates of sodium hydroxide.

The aforementioned daily records a., b., and c. shall also be reported daily to the Department of Health by telephone no later than noon of the following work day. The Department of Health may at any time request additional data or revise the frequency of this daily telephone reporting requirement.

The records shall be kept at the well location at all times during the drilling and flow testing operations and shall be made available upon request by the Department of Health or its duly authorized representative. Copies or summaries of the records shall be provided within a reasonable time upon request by the Department of Health. The records shall be retained for at least three years following the date of such records.

16. The permittee shall maintain a 24-hour telephone service to accept calls concerning this Authority to Construct. This telephone number must be operational prior to commencement of construction.

17. The permittee shall utilize mud drilling techniques to the extent possible during the well drilling operations. In no case shall air drilling be used in the construction of the geothermal well. The drilling with aerated mud or aerated water may be used in lieu of mud drilling, but should be minimized to the extent practical. Should any [inadvertent] releases of steam occur during the drilling operations, the drilling fluid weight shall be immediately increased to stop the steam flow. In no case shall any inadvertent steam releases **result in hydrogen sulfide emissions of five (5.0) pounds per hour or more, or** exceed seven (7) minutes in duration in any one hour. If the inadvertent steam releases cannot be controlled by increasing the fluid weight or exceeds seven (7) minutes in duration **in any one hour**, the permittee shall take immediate action to shut-in the well.

Records of each steam release incident shall be maintained and include as a minimum, date, time and duration of the incident, the estimated resultant emissions, and any corrective measures taken. The records shall be in a permanent form suitable for inspection, shall be made available upon request by the Department of Health, and shall be retained for at least three (3) years following the date of such records.

18. Steam production rates and hydrogen sulfide concentrations shall be measured to determine hydrogen sulfide emissions in pounds per hour. A sodium hydroxide treatment mole ratio of 4 to 1 (NaOH/H2S) will be used initially and the abatement efficiency monitored. The optimum mole ratios will be determined during the hydrogen sulfide abatement operations. A specific chemical treatment plan shall be submitted to the Department of Health prior to the commencement of flow testing. A copy of the plan shall

be maintained at the site at all times and supervisory personnel shall be aware of its provisions at all times.

19. The permittee shall promptly notify the Department of Health should any toxic emissions be encountered of public health concern and where dispersion into the ambient air was the mitigative action.

20. The permittee shall perform once on each well, testing and analyses for all of the following constituents of the steam condensate, steam, particulates and/or gases emanating from each well:

STEAM CONDENSATE/TOTAL STEAM	**GAS PHASE**
Benzene	Benzene
Ammonium (Total)	Hydrogen Sulfide
Arsenic	Ammonia
Lead	Radon 222 and daughters
Cadmium	Mercury Vapor
Bicarbonate and Carbonate	Methane
Sulfates	Non-Methane Hydrocarbons
Chlorides	Carbon dioxide
Nitrates	Sulfur dioxide
Boron (Total)	NESHAPS - pollutants as requested
Hydrogen Sulfide (Total)	
Fluorides (Total)	
Total Sulfur	
Mercury (Total)	
pH	
Total Dissolved Solids	
Total Suspended Solids	
Percent Noncondensibles	

21. The drilling rig diesel engine generators and pumps shall be fired only on diesel fuel oil no. 2 with a maximum sulfur content not to exceed 0.5 percent by weight. The permittee shall maintain records on the total amount of fuel oil consumed by all the diesel engines for the drilling of each well. The total gallons of fuel oil consumed shall be submitted to the Department of Health at the completion of each well.

22. Unabated well venting shall be allowed only after the permittee has checked with the National Weather Service and is assured of meteorological conditions appropriate for good dispersion and minimal air quality impact. In no case shall the well venting commence if the average wind speed at the well site is less than 4 meters per second **(8.9 miles per hour)**. Prior to well venting, the Department must be informed in writing a minimum of two (2) days prior to commencement and so concur. The public shall be notified a minimum of 24-hours in advance by notices in the newspapers of general circulation in Hawaii County. In addition, the permittee shall make a reasonable effort to notify all residents living within 3,500 feet of the permittee's property boundary a minimum of 24-hours in advance of open venting of each well and pipeline cleanout. In preparation for flow testing, each well shall be allowed to open vent only during the daytime and no more than a total of four (4) hours.

    In no case shall any well venting coincide with any pipeline cleanouts or well flow testing operations, or commence if the power plant emergency steam release facility is being utilized. If emergency steam releases from the power plant occur during the venting of any well, venting of that well shall be terminated as quickly as practical.

23. [Should any of the air quality monitoring stations indicate an ambient hydrogen sulfide, one-hour average concentration greater than 100 ppb, the permittee shall take immediate action to the extent practical to reduce all wellfield emissions. Within four (4) hours of the exceedance, the permittee shall reduce all wellfield hydrogen sulfide emissions associated with wellfield construction operations, including but not limited to drilling, flow testing, venting, etc., by a minimum of 50 percent of the level during the event. Following the reduction in project emissions, if the monitoring stations still indicate ambient hydrogen sulfide concentrations in excess of 100 ppb (one-hour average), the permittee shall cease all drilling operations and shut-in all wells under construction, unless the permittee can conclusively show to the Department of Health that the project operations and emissions are not contributing any impact to monitoring site. If the project emissions have been reduced, the permittee shall maintain the emissions at this reduced level until such time the Department of Health is assured that the resumption of full activity shall not result in another exceedance of the ambient level of 100 ppb (one-hour average).]

In no case shall the well drilling, flow testing, venting operations, or well equipment failure or malfunction of any of the fourteen (14) geothermal exploratory/developmental wells cause or contribute to an exceedance of the hydrogen sulfide ambient level of 100 ppb (including background) on a one-hour average at or beyond the project boundary. Should any of the approved air quality monitoring stations indicate a hydrogen sulfide ambient concentration greater than 100 ppb (including background) on a one-hour average, the permittee shall immediately notify the Department of Health, ceasing all well drilling with aerated mud or aerated water, well flow testing, and well venting operations, and shutting in those wells experiencing equipment failure or malfunction, which result in emissions of hydrogen sulfide. The affected wellfield construction activities shall be allowed to proceed only after the permittee has satisfactorily demonstrated to the Department of Health that the contributions from the well drilling with aerated mud or aerated water, well flow testing, well venting operations or well equipment repair will not result in or contribute to the exceedance of the hydrogen sulfide ambient concentration of 100 ppb (including background) on a one-hour average.

The permittee shall submit to the Department of Health a written follow-up report within [two (2)] **five (5)** days of the occurrence. The report shall include the date, time and duration of the exceedance(s), the status of all project operations during the exceedance, the estimated project emissions and any other emission sources that may have contributed to the exceedance, and all corrective measures and actions to reduce project emissions to a minimum. Compliance with this notification provision shall not excuse or otherwise constitute a defense to any violation(s) of this permit or of any law or regulations.

24. [The drilling, flow testing, and venting operations of any of the fourteen (14) geothermal exploratory/developmental wells shall not cause or contribute to an exceedance of the hydrogen sulfide ambient level of 100 ppb on a one-hour average at or beyond the project boundary.]

25. The permittee may be required to install a control system acceptable to the Department of Health for the rapid throttling of steam flow and well shut-in on each developmental well prior to the well being connected to a resource distribution system. The requirement for a control system may be so specified in the subsequent Permit to Operate.

26. To prevent well blowouts, the permittee shall employ good drilling practices with proper blowout prevention equipment and experienced personnel in the drilling of the exploratory/developmental wells. Drilling supervisors shall be certified in blowout prevention at a minimum of once every two years by a recognized training center. In the unlikely event of a well blowout, the permittee shall immediately proceed with measures to kill or gain control of the well and notify the Department of Health.

    The permittee shall submit to the Department of Health a written report within five (5) days of the blowout. The report shall include, as a minimum, the probable cause of the blowout, the actions that have or will be taken, the estimated time before the well is controlled, an analysis of the air quality impact from the unabated emissions, and a monitoring plan to determine the actual air quality impact resulting from the blowout. A status report shall be submitted to the Department of Health on a weekly basis until such time the control of the well is established.

27. During those periods of normal power plant and **normal** wellfield operations, the combined emissions of hydrogen sulfide from the 25 MW geothermal power plant **(A-834)** and associated wellfield **(A-833)** shall not cause an increase in the [ambient] hydrogen sulfide **ambient** concentration in excess of 5 ppb [(one-hour average)] (above background**)** **on a one-hour average** at or beyond the project boundary **as monitored at any of the approved air quality monitoring stations and so identified in the monthly monitoring report**. [During those periods when geothermal well drilling, well flow testing, or emergency steam release may be occurring, whether separately, in any combination, or whether in combination with periods of normal power plant or wellfield operation, the combined emissions of hydrogen sulfide from these sources shall not cause an increase in the ambient hydrogen sulfide concentration in excess of 25 ppb (one-hour average) above background at or beyond the project boundary.] **As used in this context, a normal power plant operation is a power plant which is operating without any upsets, equipment failure, malfunction or which is otherwise operating normally. A normal wellfield operation is a wellfield in which no well drilling, flow testing, or venting activities are occurring and where the completed wells are not experiencing any equipment failure or malfunction and are either shut-in, being used as an injection well, or connected to a sound geothermal resource distribution system.**

28. [For any ambient hydrogen sulfide concentration in excess of 5 ppb (one-hour average) above background as indicated by any air quality monitoring station, the permittee has the burden of proving that operation of the 25 MW geothermal power plant and wellfield did not cause the hydrogen sulfide impact in excess of 5 ppb (one-hour average), or proving that the power plant or wellfield had experienced an operational upset, equipment failure, malfunction or was otherwise not operating normally. For any ambient hydrogen sulfide concentration in excess of 25 ppb (one-hour average) above background as indicated by any air quality monitoring station, the permittee has the burden of proving that operation of the 25 MW geothermal power plant and wellfield did not cause the hydrogen sulfide concentration in excess of 25 ppb (one-hour average), or proving that the measured impact occurred during the vertical venting of a geothermal well or cleanout of the steam production pipelines.]

    Excluding periods of well venting and pipeline cleanout, the combined emissions of hydrogen sulfide from the 25 MW geothermal power plant (A-834) and associated wellfield (A-833) shall not cause an increase in the hydrogen sulfide ambient concentration in excess of 25 ppb (above background) on a one-hour average at or beyond the project boundary as monitored at any of the approved air quality monitoring stations and so identified in the monthly monitoring report.

Should any of the approved air quality monitoring stations indicate a hydrogen sulfide ambient concentration greater than 25 ppb (above background) on a one-hour average, the permittee shall immediately notify the Department of Health and the Hilo District Health Office and shall cease all geothermal well drilling with aerated mud or aerated water, well flow testing, and scheduled project maintenance, and shut-in those wells experiencing equipment failure or malfunction, which result in emissions of hydrogen sulfide. The affected well drilling, flow testing, scheduled maintenance, and well equipment repair shall be allowed to proceed only after the permittee has satisfactorily demonstrated to the Department of Health that the hydrogen sulfide emissions from the affected well drilling, flow testing, scheduled maintenance, well equipment or power plant repairs, power plant emergency steam release, or normal power plant operation, whether separately or in any combination, did not or will not cause an increase in the hydrogen sulfide ambient concentration in excess of 25 ppb (above background) on a one-hour average.

CERTIFIED MAIL
RETURN RECEIPT REQUESTED

March 16, 1990

90-A100
File #834

Mr. Maurice A. Richard
Regional Development Manager
Puna Geothermal Venture
101 Aupuni Street, Suite 1014-B
Hilo, Hawaii 96720

Dear Mr. Richard:

Subject: Modification to Authority to Construct No. A-834-796
25 MW Geothermal Power Plant
Located at TMK: 1-4-01:2 and 1-4-01:19, Kilauea Lower East Rift Zone, Puna, Hawaii

Pursuant to Chapter 342B, Hawaii Revised Statutes, and Chapter 11-60, Hawaii Administrative Rules, the Department of Health (DOH) hereby modifies the subject Authority to Construct No. A-834-796.

The following modified special conditions supersede the corresponding special conditions of Attachment II issued with ATC No. A-834-796 dated February 6, 1990:

Special Condition No. 6

Pipeline cleanouts shall be allowed only after the permittee has checked with the National Weather Service and is assured of meteorological conditions appropriate for good dispersion and minimal air quality impact. In no case shall any pipeline cleanout commence if the average wind speed at the pipeline exhaust site is less than four (4) meters per second (8.9 miles per hour). In no case shall any pipeline cleanout coincide with any well venting, well flow testing, or well drilling with aerated water or aerated mud. Prior to any pipeline cleanout, the Department of Health must be informed in writing, a minimum of two (2) days prior to commencement and so concur. The public shall be notified a minimum of 24-hours in advance by notices in the newspapers of general circulation in Hawaii County. In addition, the permittee shall make a reasonable effort to notify all residents living within 3,500 feet of the permittee's property boundary a minimum of 24-hours in advance of any pipeline cleanout. Each pipeline cleanout shall not exceed 20 minutes in duration and shall occur only in the daytime.

Special Condition No. 7

The permittee shall install, operate, and maintain a minimum of one (1) meteorological and three (3) air quality monitoring stations. The monitoring stations required in any permit for the wellfield may be used towards fulfilling this requirement.

Prior to the commencement of construction, the permittee shall submit for the Department of Health's approval the siting of the air quality and meteorological monitoring stations. The air quality and meteorological monitoring stations shall be fully operational prior to the commencement of plant operations. The permittee shall maintain a file of all measurements, including the monitoring system performance evaluations; calibration checks; and adjustments and maintenance performed on the system or devices. The measured data shall meet U.S. EPA capture requirements and quality assurance guidelines. As a minimum, a quality assurance check shall be conducted on each monitoring station every-other-day.

The air quality monitors shall be equipped with an alarm or acceptable equivalent system that will immediately notify the permittee of ambient hydrogen sulfide concentrations in excess of 25 ppb (above background) and 100 ppb (including background) on a one-hour average. The permittee shall immediately notify the Department of Health and the Hilo District Health Office of any exceedance above 25 ppb (above background) and 100 ppb (including background) on a one-hour average.

Two (2) copies of the data file in a format acceptable to the Department of Health shall be submitted on an annual basis. The data file shall be in a format that can be utilized by a personal computer for ready extraction of data. The air quality and meteorological data shall be summarized and submitted monthly in writing to the Department of Health. Additional information on the monitoring stations and on the data collected shall be submitted upon request by the Department of Health.

Special Condition No. 13

The permittee shall immediately notify the Department of Health of any operational upsets, equipment failure or malfunction which would allow an increase in the emissions of hydrogen sulfide, particulate matter or isopentane. The permittee shall apply best available control technology for the air emissions and take immediate steps to correct the condition. The permittee shall take appropriate action in accordance with Special Condition Nos. 15, 17 and 18 if the hydrogen sulfide ambient concentration exceeds the specified limits in Special Condition Nos. 15, 17 and 18. In addition, a written report shall be submitted to the Department of Health within five (5) days of the occurrence. The report shall include a description of the malfunctioning equipment or abnormal operation, the date of the initial failure, the estimated resultant emissions, time and duration of the event, and the methods utilized to restore normal operations. Compliance with this notification provision shall not excuse or otherwise constitute a defense for any violation(s) of this permit, law, rule or order which results from the operational upset, equipment failure or malfunction.

Special Condition No. 15

The operation of the 25 MW geothermal power plant during periods of operational upsets, equipment failure or malfunctions shall not cause or contribute to an exceedance of the hydrogen sulfide ambient level of 100 ppb (including background) on a one-hour average at or beyond the project boundary. Should any of the approved air quality monitoring stations indicate a hydrogen sulfide ambient concentration greater than 100 ppb (including background) on a one-hour average, the permittee shall take immediate action terminating, within two (2) hours of the exceedance, all power plant activities not associated with normal power plant operations and contributing to hydrogen sulfide emissions. Following the reduction in project emissions, if the monitoring stations still indicate hydrogen sulfide ambient concentrations in excess of 100 ppb (including background) on a one-hour average, the permittee shall curtail the power plant operations, unless the permittee can conclusively show to the Department of Health that the project operations and emissions are not contributing any impact to the monitoring site. If the hydrogen sulfide ambient concentration is below 100 ppb (including background) on a one-hour average after the project emissions have been reduced, the permittee shall maintain the emissions at this reduced level until such time the Department of Health is assured that the resumption of full activity shall not result in another exceedance of the hydrogen sulfide ambient level of 100 ppb (including background) on a one-hour average.

The permittee shall submit a written report to the Department of Health within five (5) days of the occurrence. The report shall include the date, time and duration of the exceedance, the estimated project emissions and any other emission sources that may have contributed to the exceedance, and all corrective measures and actions taken to reduce project emissions to a minimum. Compliance with this notification provision shall not excuse or otherwise constitute a defense for any violation (s) of this permit, law, rule or order.

Special Condition No. 17

During those periods of normal power plant and normal wellfield operations, the combined emissions of hydrogen sulfide from the 25 MW geothermal power plant (A-834) and associated wellfield (A-833) shall not cause an increase in the hydrogen sulfide ambient concentration in excess of 5 ppb (above background) on a one-hour average at or beyond the project boundary as monitored at any of the approved air quality monitoring stations and so identified in the monthly monitoring report. As used in this context, a normal power plant operation is a power plant which is operating without any upsets, equipment failure, malfunction or which is otherwise operating normally. A normal wellfield operation is a wellfield in which no well drilling, flow testing, or venting activities are occurring and where the completed wells are not experiencing any equipment failure or malfunction and are either shut-in, being used as an injection well, or connected to a sound geothermal resource distribution system.

Special Condition No. 18

Excluding periods of well venting and pipeline cleanout, the combined emissions of hydrogen sulfide from the 25 MW geothermal power plant (A-834) and associated wellfield (A-833) shall not cause an increase in the hydrogen sulfide ambient concentration in excess of 25 ppb (above background) on a one-hour average at or beyond the project boundary as monitored at any of the approved air quality monitoring stations and so identified in the monthly monitoring report.

Should any of the approved air quality monitoring stations indicate a hydrogen sulfide ambient concentration greater than 25 ppb (above background) on a one-hour average, the permittee shall immediately notify the Department of Health and the Hilo District Health Office and shall cease all geothermal well drilling with aerated mud or aerated water, well flow testing, and scheduled project maintenance, and shut-in those wells experiencing equipment failure or malfunction, which result in emissions of hydrogen sulfide. The affected well drilling, flow testing, scheduled maintenance, and well equipment repair shall be allowed to proceed only after the permittee has satisfactorily demonstrated to the Department of Health that the hydrogen sulfide emissions from the affected well drilling, flow testing, scheduled maintenance, well equipment or power plant repairs, power plant emergency steam release, or normal power plant operation, whether separately or in any combination, did not or will not cause an increase in the hydrogen sulfide ambient concentration in excess of 25 ppb (above background) on a one-hour average.

The following special condition of Attachment II issued with ATC No. A-834-796 dated February 6, 1990 is hereby deleted:

Special Condition No. 16

The operation of the 25 MW geothermal power plant during periods of operational upsets, equipment failure or malfunctions shall not cause or contribute to an exceedance of the hydrogen sulfide ambient level of 100 ppb on a one-hour average at or beyond the project boundary.

All other special conditions of Attachment II (Special Condition Nos. 1, 2, 3, 4, 5, 8, 9, 10, 11, 12, 14, 19 and 20) issued with ATC No. A-834-796 dated February 6, 1990 shall not be affected and shall remain valid.

These modifications shall become final twenty (20) days after receipt, unless before the twenty (20) days expire, Puna Geothermal Venture submits a written request to the Director of Health for a hearing pursuant to Chapters 91 and 342B, Hawaii Revised Statutes. If a hearing is requested, it will be held at a date, time, and place to be specified later and conducted in accordance with Chapter 91, Hawaii Revised Statutes, and the rules of Practice and Procedure of the Department of Health.

Very truly yours,

JOHN C. LEWIN, M.D.
Director of Health

WN/sk
cc: DHSA, Hawaii

COPY FOR YOUR INFORMATION

March 16, 1990
Ramseyer

ATTACHMENT II. SPECIAL CONDITIONS OF AUTHORITY TO CONSTRUCT, NO. A-834-796
APPLICATION NO. A-834
POWER PLANT

In addition to the standard conditions of the Authority to Construct, this permit is subject to the following special conditions:

1. The permit conditions prescribed herein may at any time be revised by the Department of Health to conform to any Federal or State promulgated air quality rules on geothermal facilities.

2. The total fugitive isopentane emissions from all ten (10) Ormat Energy Converter (OEC) modules shall not exceed 0.4 lbs/hr or exceed 1000 ppm from any seal, flange, valve or any other fugitive emission point when measured from a distance of two (2) inches from the point. The permittee shall perform measurements on all fugitive isopentane emission points, as a minimum, on a weekly basis. The permittee shall take immediate corrective actions upon identifying any isopentane emissions in excess of 1000 ppm when measured from a distance of two (2) inches.

3. Records shall be maintained on all isopentane emission measurements, the amount of gallons of isopentane purchased, the amount of isopentane transferred to and from the OEC modules, and the amount of isopentane released to the atmosphere. The records shall be in a permanent form suitable for inspection, shall be made available upon request by the Department of Health, and shall be retained for at least three (3) years following the date of such records. A report on the amount of isopentane released to the atmosphere shall be submitted to the Department of Health on an annual basis.

4. The geothermal fluids injection system shall include at least two (2) geothermal injection wells, a spare fluid pump, and a spare noncondensable gas compressor. The backup injection system equipment shall be maintained in good operating condition at all times and shall be utilized immediately upon identification of any malfunctioning equipment.

   In the event of an equipment malfunction or upset condition which results in a situation where the two geothermal injection wells are not capable of handling the total geothermal resource being utilized by the power plant, the power plant production and the associated geothermal resource being used shall be immediately reduced accordingly to the handling capacity of the two injection wells.

5. The diesel engine generator and the diesel firewater pump shall be fired only on diesel fuel oil no. 2 with a maximum sulfur content not to exceed 0.5% by weight.

6. Pipeline cleanouts shall be allowed only after the permittee has checked with the National Weather Service and is assured of meteorological conditions appropriate for good dispersion and minimal air quality impact. In no case shall any pipeline cleanout commence if the average wind speed at the pipeline exhaust site is less than four (4) meters per second (**8.9 miles per hour**). In no case shall any pipeline cleanout coincide with any well venting, well flow testing, or well drilling with aerated water or aerated mud. Prior to any pipeline cleanout, the Department of Health must be informed in writing, a minimum of two (2) days prior to commencement and so concur. The public shall be notified a minimum of 24-hours in advance by notices in the newspapers of general circulation in Hawaii County. In addition, the permittee shall make a

reasonable effort to notify all residents living within 3,500 feet of the permittee's property boundary a minimum of 24-hours in advance of any pipeline cleanout. Each pipeline cleanout shall not exceed 20 minutes in duration and shall occur only in the daytime.

7. The permittee shall install, operate, and maintain a minimum of one (1) meteorological and three (3) air quality monitoring stations. The monitoring stations required in any permit for the wellfield may be used towards fulfilling this requirement.

   Prior to the commencement of construction, the permittee shall submit for the Department of Health's approval the siting of the air quality and meteorological monitoring stations. The air quality and meteorological monitoring stations shall be fully operational prior to the commencement of plant operations. The permittee shall maintain a file of all measurements, including the monitoring system performance evaluations; calibration checks; and adjustments and maintenance performed on the system or devices. The measured data shall meet U.S. EPA capture requirements and quality assurance guidelines. As a minimum, a quality assurance check shall be conducted on each monitoring station every-other-day.

   The air quality monitors shall be equipped with an alarm or acceptable equivalent system that will immediately notify the permittee of ambient hydrogen sulfide concentrations in excess of 25 ppb **(above background)** and 100 ppb **(including background)** on a one-hour average. The permittee shall immediately notify the Department of Health and the Hilo District Health Office of any exceedance above **25 ppb (above background) and** 100 ppb **(including background) on a one-hour average.**

   Two (2) copies of the data file in a format acceptable to the Department of Health shall be submitted on an annual basis. The data file shall be in a format that can be utilized by a personal computer for ready extraction of data. The air quality and meteorological data shall be summarized and submitted monthly in writing to the Department of Health. Additional information on the monitoring stations and on the data collected shall be submitted upon request by the Department of Health.

8. At the discretion of the Director of Health the permittee may at any time be required to install, operate, and maintain additional air quality and meteorological monitoring stations, but only after due notice to the permittee on the reasons for the proposed change and providing the permittee an opportunity to respond within seven (7) days.

9. All access roads into the permittee's property shall be limited to authorized personnel only. Twenty-four hour staffing shall be in place during plant operations.

10. The emergency steam release facility, consisting of two (2) rock mufflers, chemical storage tank(s) and associated equipment, shall be installed, maintained, and be fully operational prior to commencement of plant operations. Each rock muffler shall be capable of handling a steam flow rate of 570,000 lbs/hr or 100 percent of the total power plant steam flow, whichever is greater.

11. The emergency steam release facility shall only be utilized under one or more of the following conditions:

    a) Failure of the electrical transmission lines out of the power plant or some incident that tripped all the steam turbines and OEC units;

    b) Complete upset of the geothermal fluid injection system;

c) Pressure in the steam lines exceeds safety design set points; or

d) Any upset situation which would otherwise result in a release of unabated steam to the atmosphere.

12. The emergency steam release facility shall be equipped and maintained at all times with a minimum three-day operating storage capacity of sodium hydroxide. The chemical abatement system shall operate automatically when steam is released through the rock muffler(s). The hydrogen sulfide concentrations shall be continuously monitored both downstream and upstream of the chemical injection point. A sodium hydroxide treatment mole ratio of 4 to 1 ($NaOH/H_2S$) will be used initially and the abatement efficiency monitored. The optimum mole ratios will be determined during the hydrogen sulfide abatement operations.

    Upon utilizing the emergency steam release facility, the permittee shall take immediate action to the extent practical to reduce the steam flow and perform the necessary corrective actions. The steam flow rate shall be reduced, as a minimum, to 50 percent of full flow within four (4) hours after initiating the use of the emergency steam release facility.

13. The permittee shall immediately notify the Department of Health of any operational upsets, equipment failure or malfunction which would allow an increase in the emissions of hydrogen sulfide, particulate matter or isopentane. **The permittee shall apply best available control technology for the air emissions and take immediate steps to correct the condition. The permittee shall take appropriate action in accordance with Special Condition Nos. 15, 17 and 18 if the hydrogen sulfide ambient concentration exceeds the specified limits in Special Condition Nos. 15, 17 and 18.** In addition, a written report shall be submitted to the Department of Health within five (5) days of the occurrence. The report shall include a description of the malfunctioning equipment or abnormal operation, the date of the initial failure, the estimated resultant emissions, time and duration of the event, and the methods utilized to restore normal operations. Compliance with this notification provision shall not excuse or otherwise constitute a defense for any violation(s) of this permit, law, rule or order which results from the operational upset, equipment failure or malfunction.

14. The permittee shall maintain a 24-hour telephone service to accept calls concerning this Authority to Construct. This telephone number must be fully operational prior to commencement of construction.

15. [Should any of the air quality monitoring stations indicate an ambient hydrogen sulfide, one-hour average concentration greater than 100 ppb, the permittee shall take immediate action to the extent practical to reduce all power plant emissions. Within four (4) hours of the exceedance, the permittee shall terminate all power plant activities not associated with normal power plant operations and contributing to hydrogen sulfide emissions. Following the reduction in project emissions, if the monitoring stations still indicate ambient hydrogen sulfide concentrations in excess of 100 ppb (one-hour average), the permittee shall curtail the power plant operations, unless the permittee can conclusively show to the Department of Health that the project operations and emissions are not contributing any impact to monitoring site. If the ambient hydrogen sulfide concentration is below 100 ppb (one-hour average) after the project emissions have been reduced, the permittee shall maintain the emissions at this reduced level until such time the Department of Health is assured that the

resumption of full activity shall not result in another exceedance of the ambient level of 100 ppb (one-hour average).]

The operation of the 25 MW geothermal power plant during periods of operational upsets, equipment failure or malfunctions shall not cause or contribute to an exceedance of the hydrogen sulfide ambient level of 100 ppb (including background) on a one-hour average at or beyond the project boundary. Should any of the approved air quality monitoring stations indicate a hydrogen sulfide ambient concentration greater than 100 ppb (including background) on a one-hour average, the permittee shall take immediate action terminating, within two (2) hours of the exceedance, all power plant activities not associated with normal power plant operations and contributing to hydrogen sulfide emissions. Following the reduction in project emissions, if the monitoring stations still indicate hydrogen sulfide ambient concentrations in excess of 100 ppb (including background) on a one-hour average, the permittee shall curtail the power plant operations, unless the permittee can conclusively show to the Department of Health that the project operations and emissions are not contributing any impact to the monitoring site. If the hydrogen sulfide ambient concentration is below 100 ppb (including background) on a one-hour average after the project emissions have been reduced, the permittee shall maintain the emissions at this reduced level until such time the Department of Health is assured that the resumption of full activity shall not result in another exceedance of the hydrogen sulfide ambient level of 100 ppb (including background) on a one-hour average.

The permittee shall submit a written report to the Department of Health within [two (2)] **five (5)** days of the occurrence. The report shall include the date, time and duration of the exceedance, the estimated project emissions and any other emission sources that may have contributed to the exceedance, and all corrective measures and actions taken to reduce project emissions to a minimum. Compliance with this notification provision shall not excuse or otherwise constitute a defense for any violation(s) of this permit, law, rule or order.

16. [The operation of the 25 MW geothermal power plant during periods of operational upsets, equipment failure or malfunctions shall not cause or contribute to an exceedance of the hydrogen sulfide ambient level of 100 ppb on a one-hour average at or beyond the project boundary.]

17. During those periods of normal power plant and **normal** wellfield operations, the combined emissions of hydrogen sulfide from the 25 MW geothermal power plant **(A-834)** and associated wellfield **(A-833)** shall not cause an increase in the [ambient] hydrogen sulfide **ambient** concentrations in excess of 5 ppb [(one-hour average)] (above background) **on a one-hour average** at or beyond the project boundary **as monitored at any of the approved air quality monitoring stations and so identified in the monthly monitoring report.** [During those periods when geothermal well drilling, well flow testing, or emergency steam release may be occurring, whether separately, in any combination, or whether in combination with periods of normal power plant or wellfield operation, the combined emissions of hydrogen sulfide from these sources shall not cause an increase in the ambient hydrogen sulfide concentration in excess of 25 ppb (one-hour average) above background at or beyond the project boundary.] **As used in this context, a normal power plant operation is a power plant which is operating without any upsets, equipment failure, malfunction or which is otherwise operating normally. A normal wellfield operation is a wellfield in which no well drilling, flow testing, or venting activities are occurring and where the completed wells are not experiencing any equipment failure or malfunction and are either shut-in,**

being used as an injection well, or connected to a sound geothermal resource distribution system.

18. [For any ambient hydrogen sulfide concentrations in excess of 5 ppb (one-hour average) above background as indicated by any air quality monitoring station, the permittee has the burden of proving that operation of the 25 MW geothermal power plant and wellfield did not cause the hydrogen sulfide impact in excess of 5 ppb (one-hour average), or proving that the power plant or wellfield had experienced an operational upset, equipment failure, malfunction or as otherwise not operating normally. For any ambient hydrogen sulfide concentration in excess of 25 ppb (one-hour average) above background as indicated by any air quality monitoring station, the permittee has the burden of proving that operation of the 25 MW geothermal power plant and wellfield did not cause the hydrogen sulfide concentration in excess of 25 ppb (one-hour average), or proving that the measured impact occurred during the vertical venting of a geothermal well or cleanout of the steam production pipelines.]

Excluding periods of well venting and pipeline cleanout, the combined emissions of hydrogen sulfide from the 25 MW geothermal power plant (A-834) and associated wellfield (A-833) shall not cause an increase in the hydrogen sulfide ambient concentration in excess of 25 ppb (above background) on a one-hour average at or beyond the project boundary as monitored at any of the approved air quality monitoring stations and so identified in the monthly monitoring report.

Should any of the approved air quality monitoring stations indicate a hydrogen sulfide ambient concentration greater than 25 ppb (above background) on a one-hour average, the permittee shall immediately notify the Department of Health and the Hilo District Health Office and shall cease all geothermal well drilling with aerated mud or aerated water, well flow testing, and scheduled project maintenance, and shut-in those wells experiencing equipment failure or malfunction, which result in emissions of hydrogen sulfide. The affected well drilling, flow testing, scheduled maintenance, and well equipment repair shall be allowed to proceed only after the permittee has satisfactorily demonstrated to the Department of Health that the hydrogen sulfide emissions from the affected well drilling, flow testing, scheduled maintenance, well equipment or power plant repairs, power plant emergency steam release, or normal power plant operation, whether separately or in any combination, did not or will not cause an increase in the hydrogen sulfide ambient concentration in excess of 25 ppb (above background) on a one-hour average.

19. During normal power plant operations, the hydrogen sulfide emissions from the 25 MW geothermal power plant shall not exceed one pound per hour (three-hour average). During periods of malfunction or regularly scheduled maintenance, best available control technology shall be applied for the hydrogen sulfide emissions.

20. The Department of Health may at any time with reasonable cause, request the permittee to install, operate, and maintain emission monitors to continuously measure and record the hydrogen sulfide and isopentane emissions at any specified location in the power plant.

REF:WL-KO MAR 22 1990

Mr. Duane Kanuha, Director
Planning Department
County of Hawaii
25 Aupuni Street, Room 109
Hilo, Hawaii 96720

Dear Mr. Kanuha:

This is in reference to your letter of February 22, 1990 proposing the establishment of a technical task force to expedite the joint review of environmental monitoring programs associated with geothermal development activities.

I support your proposal and have authorized my staff to assist you in whatever way possible in your review of the monitoring programs submitted by Puna Geothermal Venture.

Please contact Manabu Tagomori, Deputy Director, at 548-7533 to coordinate the meetings of the task force.

Very truly yours,

WILLIAM W. PATY

MT:DN:GSM:ko

Bernard K. Akana
Mayor
Duane Kanuha
Director
William L. Moore
Deputy Director

Planning Department

25 Aupuni Street, Rm. 109 • Hilo, Hawaii 96720 • (808) 961-8288

RECEIVED
DEPT. OF LAND & NATURAL RESOURCES STATE OF HAWAII

February 22, 1990

Mr. William Paty, Chairman
Board of Land and Natural Resources
P. O. Box 621
Honolulu, HI 96804

Dr. John C. Lewin, Director
Department of Health
P. O. Box 3378
Honolulu, HI 96801

Dear ~~Mr. Paty~~ Bill and ~~Dr. Lewin~~ Jack:

Geothermal Resource Permit No. 2
Puna Geothermal Venture (PGV) - 25 MW (net) Development
Kapoho, Hawaii TMK: 1-4-01: por. 2, 3, por. 19, & 58

Geothermal Resource Permit No. 2 issued by our Planning Commission included several conditions which requires PGV to submit monitoring programs to the Planning Department for review and approval. These conditions also require the Planning Department to consult with the Department of Health and Department of Land and Natural Resources on these monitoring programs. We have recently received a Noise Monitoring Program, a Hydrologic Monitoring Program, and a Meteorological and Air Quality Monitoring Program from PGV.

I propose the establishment of a technical task force to expedite the joint review of such programs. Our staff (Planning, DOH, & DLNR) have already met at least once in response to PGV's request prior to this recent submittal. I propose that the staff involved at this earlier meeting continue in this effort.

For the immediate task, I would like to suggest the following:

Rodney Nakano, Hawaii County Planning
Dean Nakano, DOWALD
Wilfred Nagamine, DOH-Air
Chauncey Heu, DOH-Water
Tom Anamizu, DOH-Noise

It is my understanding that PGV has already distributed some of these programs to the above named staff. My staff will contact each of them to coordinate the review and to initiate a joint review session, if necessary. I am hopeful that both of you will find this proposal to be acceptable and will authorize your appropriate staff to this end.

Please call me as soon as possible if there are any questions.

Sincerely,

DUANE KANUHA
Planning Director

RKN:aeb

JOHN WAIHEE
GOVERNOR OF HAWAII

STATE OF HAWAII
DEPARTMENT OF HEALTH
P. O. BOX 3378
HONOLULU, HAWAII 96801

JOHN C. LEWIN, M.D.
DIRECTOR OF HEALTH

In reply, please refer to:
EPHSD

March 16, 1990

Mr. Maurice A. Richard
Hawaii Regional Development Manager
Puna Geothermal Venture
101 Aupuni Street, Suite 1014-B
Hilo, Hawaii 96720

Dear Mr. Richard:

SUBJECT: PUNA GEOTHERMAL VENTURE PROJECT
UNDERGROUND INJECTION CONTROL (UIC)
UIC APPLICATION NO. UH-1529

This is to inform you that the Department of Health has completed its review of your preliminary application and has determined that the conditions for the granting of approval to construct up to three (3) dedicated injection wells and up to nine (9) production/injection wells at the subject facility have been satisfied. Therefore, you are hereby granted approval to construct the proposed injection wells as indicated in your preliminary plans. You are requested to notify the Safe Drinking Water Branch within 24 hours of the commencement and completion of construction activities. Unless construction is commenced within 180 days from the date of this letter, this approval to construct shall be terminated other applicable state and federal statutes and rules must also be complied with before construction may begin. Copies of this approval and the preliminary application must be kept on the construction site for inspection by department personnel.

Please be advised that <u>this approval to construct does not constitute a permit to operate</u> the injection facility upon completion of construction. The issuance of a UIC permit to operate will be based on the satisfactory review and acceptance of the following items:

1. A registered professional engineer or qualified geologist report (hereinafter "report") which includes the data and results of the injection tests.

2. A Hydrologic (groundwater) Monitoring Program (HMP).

3. A production well and injection well Casing Monitoring Program (CMP).

The report as outlined in the application instructions under the heading "Construction of New Wells or Modification of Existing Wells" should be submitted following the construction and testing of the injection wells.

The department acknowledges the submittal of your hydrologic monitoring program (HMP) as prepared by Science Applications International Corporation. The HMP is currently being reviewed by the Safe Drinking Water Branch. Upon completion of the review, the department's comments will be submitted to you.

The department anticipates the submittal of your CMP as it will relate to the protection of the groundwater quality of the shallow aquifer. Your CMP will also be reviewed by the Division of Water and Land Development as it does relate to their regulations on geothermal activity.

If you have any questions regarding the processing of your application, please contact the Safe Drinking Water Branch at telephone 543-8258.

Sincerely,

James K. Ikeda

JAMES K. IKEDA, Acting Chief
Environmental Management Division

CH:la

cc: 1) Rodney Nakano
Planning Commission
25 Aupuni Street
Hilo, Hawaii 96720

2) Dean Nakano
Division of Water and Land Development

12 05

CERTIFIED MAIL
RETURN RECEIPT REQUESTED

February 6, 1990

90-A52
File #833

Mr. Maurice A. Richard
Regional Development Manager
Puna Geothermal Venture
101 Aupuni Street, Suite 1014-B
Hilo, Hawaii 96720

Dear Mr. Richard:

Subject: Authority to Construct (ATC) No. A-833-795
Application for ATC No. A-833
Expiration Date: February 1, 1992

An Authority to Construct in accordance with Administrative Rules, Title 11, Chapter 60, is hereby issued to **Puna Geothermal Venture for Fourteen (14) Geothermal Exploratory/ Developmental Wells located at TMK: 1-4-01:2, 1-4-01:3, 1-4-01:58 and 1-4-01:19, Kilauea Lower East Rift Zone, Puna, Hawaii.** The issuance of this permit is based on the plans, specifications, and additional information that you submitted as part of your application dated March 24, 1989 and the subsequent information submitted on June 9, 1989.

Although the Authority to Construct application is for the construction of 30 geothermal wells over the life of the project, the subject Authority to Construct permit authorizes the construction of only 14 geothermal wells which have been deemed necessary to initially supply and support the power plant operating at maximum capacity. Authority to Construct application(s) for additional geothermal wells should be submitted as the needs are identified.

The Authority to Construct is issued subject to the conditions set forth in Attachments I and II.

Also enclosed is Form AS-P-3, Application for Permit to Operate a Facility. Please submit this application with the applicable filing fee sixty (60) days prior to each well being connected and becoming a part of a distribution system which supplies geothermal resource to a power plant or facility. In addition, you must submit to the Department in writing the notification of completion of construction. The Authority to Construct must remain in effect until the Permit to Operate is granted or denied for the fourteen (14) geothermal exploratory/ developmental wells.

Very truly yours,

JOHN C. LEWIN, M.D.
Director of Health

Enclosures
cc: DHSA, Hawaii

ATTACHMENT I. STANDARD CONDITIONS OF AUTHORITY TO CONSTRUCT, NO. A-833-795
APPLICATION NO. A-833
WELLFIELD

This permit is granted in accordance with the State of Hawaii Administrative Rules, Title 11, Chapter 60, Air Pollution Control, and is subject to the following standard conditions:

1. This permit is non-transferable from person to person, from place to place, or from one piece of equipment to another.

2. This permit is automatically void if construction has not begun within one year of the date of issuance or if the work involved is suspended for one year or more.

3. This permit is automatically void when the Permit to Operate is issued or denied for all fourteen (14) exploratory/developmental wells.

4. The facility covered by this permit shall be constructed as specified in the application for Authority to Construct. There shall be no deviation unless additional or revised plans are submitted to and approved by the Department.

5. This permit is not a guarantee that the facility will receive a Permit to Operate at the end of the construction period, nor does it absolve the holder from the responsibility for the consequences of non-compliance with all Rules, Regulations, and Orders of the Department.

6. This authority, (a) shall not in any manner affect the title of the premises upon which the equipment is to be located, (b) does not release the permittee from any liability for any loss due to personal injury or property damage caused by, resulting from or arising out of the design, installation, maintenance, or operation of the proposed equipment, (c) does not release the permittee from compliance with other applicable statutes of the State of Hawaii, or with applicable local laws, regulations, or ordinances, and (d) in no manner implies or suggests that the Department, or its officers, agents, or employees, assumes any liability, directly or indirectly, for any loss due to personal injury or property damage caused by, resulting from or arising out of the design, installation, maintenance, or operation of the proposed equipment.

7. The Department is to be notified promptly in writing upon completion of the construction or installation of any equipment for which an Authority to Construct has been issued.

ATTACHMENT II. SPECIAL CONDITIONS OF AUTHORITY TO CONSTRUCT, NO. A-833-795
APPLICATION NO. A-833
WELLFIELD

In addition to the standard conditions of the Authority to Construct, this permit is subject to the following special conditions:

1. The permit conditions prescribed herein may at any time be revised by the Department of Health to conform to any Federal or State promulgated air quality rules on geothermal facilities.

2. This Authority to Construct is for fourteen (14) geothermal exploratory/developmental wells to be drilled in TMK: 1-4-01:2, 1-4-01:3, 1-4-01:58 and 1-4-01:19, Kilauea Lower East Rift Zone, Puna, Hawaii. Written notification must be submitted to and approval obtained with minimal delay from the Department of Health prior to commencement of construction of each well. Each notification shall include a drawing identifying the well location, the property boundary, access roads approaching and traversing the property, the location of the nearest residence, and the locations of the air quality monitoring stations. The status of all previous constructed wells shall be provided including a clear description of the measures taken to shut-in the well. Additional information may be requested of the permittee.

3. The Department of Health shall act on a Permit to Operate Application prior to any well approved under this permit being connected and becoming a part of a distribution system which supplies geothermal resource to a power plant or facility. Additional permit conditions may be included in the Permit to Operate.

4. No geothermal exploratory/developmental wells shall be located within 600 feet of the property boundary. If any federal, state or county permit or order stipulates a distance greater than 600 feet in which no geothermal wells can be located, the greater distance shall so apply.

5. The permittee shall install, operate, and maintain a minimum of one (1) meteorological and three (3) air quality monitoring stations. The monitoring stations required in any permit for the 25 MW power plant may be used towards fulfilling this requirement.

   Prior to the commencement of construction of each of the fourteen (14) wells, the permittee shall submit for the Department of Health's approval the siting of the air quality and meteorological monitoring stations. The air quality and meteorological monitoring stations shall be fully operational prior to the commencement of drilling operations. The permittee shall maintain a file of all measurements, including the monitoring system performance evaluations; calibration checks; and adjustments and maintenance performed on the system or devices. The measured data shall meet U.S. EPA capture requirements and quality assurance guidelines. At a minimum, a quality assurance check shall be conducted on each monitoring station every-other-day.

   The air quality monitors shall be equipped with an alarm system or an acceptable equivalent system that will immediately notify the permittee of ambient hydrogen sulfide concentrations in excess of 25 ppb and 100 ppb on a one-hour average. The permittee shall immediately notify the Department of Health and the Hilo District Health Office of any exceedance above 100 ppb.

Two (2) copies of the data file in a format acceptable to the Department of Health shall be submitted on an annual basis. The data file shall be in a format that can be utilized by a personal computer for ready extraction of data. The air quality and meteorological data shall be summarized and submitted monthly in writing to the Department of Health. Additional information on the monitoring stations and on the data collected shall be submitted upon request by the Department of Health.

6. At the discretion of the Director of Health, the permittee may at any time be required to install, operate, and maintain additional air quality and meteorological monitoring stations, but only after due notice to the permittee on the reasons for the proposed change and providing the permittee an opportunity to respond within seven (7) days.

7. The permittee shall notify the Department of Health in writing at least two (2) working days prior to the commencement, and within two (2) working days after the completion of the aerated mud or aerated water drilling, well venting, and flow testing operations, for each geothermal well.

8. Upon completion of flow testing operations, each geothermal well shall be shut-in or otherwise prevented from discharging to the atmosphere in accordance with appropriate standards of operation and maintenance and at no time be placed on continuous or standby bleed status.

9. Occasional flaring of excess hydrogen sulfide gas from the completed wells is prohibited unless such flaring is necessary to insure well integrity or safety and is conducted in such a manner that no state or national ambient air quality standards for sulfur dioxide are exceeded. Records shall be maintained on all flaring episodes, and shall include, as a minimum, the date, time and duration of the event, probable causes of the excess gas buildup, and the estimated emissions of sulfur dioxides determined through either direct or indirect measurements. The records shall be in a permanent form suitable for inspection and shall be retained for at least three (3) years following the date of such records. The permittee shall submit a written report monthly to the Department of Health on the flaring episodes which demonstrates compliance with the requirements of this condition. If flaring occurs frequently or routinely, the permittee shall install, operate, and maintain ambient sulfur dioxide monitors at each air quality monitoring station and comply with all recordkeeping requirements in accordance with Special Condition No. 5.

10. All access roads into the property shall be limited to authorized personnel only. Twenty-four hour staffing shall be in place during construction.

11. The permittee shall have proper safety devices on-site at least three days prior to commencement of air drilling. A minimum of three breathing apparati shall be available at the site and maintained by a qualified person/contractor. Wind socks shall be placed at two opposite edges of the drill site and on the drill floor. At least one person with certified hydrogen sulfide training to respond to hydrogen sulfide emergency episodes shall be on-site at all times.

12. Hydrogen sulfide abatement equipment with a minimum of 3,000 gallons of sodium hydroxide shall be on the property prior to the initiation of flow testing operations.

Chemical storage tanks shall be maintained with sodium hydroxide at all times with no less than a three-day operating supply.

13. The permittee shall monitor the hydrogen sulfide concentration and emission rate continuously in the steam by use of an electrochemical type sensor and recorder during the flow testing operations. If the abated hydrogen sulfide emission rate increases to five (5.0) pounds per hour or more, the permittee shall cease operations and shut-in the well. The Department of Health shall be so notified and the problem corrected before testing operations can continue.

    During periods of equipment failure or malfunction which result in hydrogen sulfide emissions, the permittee shall apply best available control technology for the air emissions and shall so notify the Department of Health within one (1) hour of the occurrence. The permittee shall immediately take steps to correct the condition. If repairs cannot be accomplished within twenty-four (24) hours of the occurrence, the permittee shall cease operations and shut-in the well. Within five (5) days of the occurrence, a report shall be submitted to the Department of Health in accordance with Hawaii Administrative Rules, Section 11-60-14.

14. Wet chemical tests for the determination of the hydrogen sulfide concentrations shall be conducted and recorded on a daily basis during all phases of the flow testing operations.

15. The following data shall be recorded during the flow testing operations:

    a. At least four times per 24-hour period, hydrogen sulfide ppm upstream from the injection system.

    b. At least four times per 24-hour period, injection rate of sodium hydroxide.

    c. At least four times per 24-hour period, hydrogen sulfide emission rate (lbs/hr) and concentration (ppm) downstream, after chemical injection.

    d. Daily, zero and span check of hydrogen sulfide sensor.

    e. Weekly, calibration check of hydrogen sulfide sensor.

    f. Daily, the quantity of sodium hydroxide remaining in the abatement equipment storage tanks.

    Additional entries will be made when significant changes in the resource occurs and when changes are made in injection rates of sodium hydroxide.

    The aforementioned daily records a., b., and c. shall also be reported daily to the Department of Health by telephone no later than noon of the following work day. The Department of Health may at any time request additional data or revise the frequency of this daily telephone reporting requirement.

    The records shall be kept at the well location at all times during the drilling and flow testing operations and shall be made available upon request by the Department of Health or its duly authorized representative. Copies or summaries of the records shall be provided within a reasonable time upon request by the Department of Health. The records shall be retained for at least three years following the date of such records.

16. The permittee shall maintain a 24-hour telephone service to accept calls concerning this Authority to Construct. This telephone number must be operational prior to commencement of construction.

17. The permittee shall utilize mud drilling techniques to the extent possible during the well drilling operations. In no case shall air drilling be used in the construction of the geothermal well. The drilling with aerated mud or aerated water may be used in lieu of mud drilling, but should be minimized to the extent practical. Should any inadvertent releases of steam occur during the drilling operations, the drilling fluid weight shall be immediately increased to stop the steam flow. In no case shall any inadvertent steam releases exceed seven (7) minutes in duration in any one hour. If the inadvertent steam releases cannot be controlled by increasing the fluid weight or exceeds seven (7) minutes in duration, the permittee shall take immediate action to shut-in the well.

    Records of each steam release incident shall be maintained and include as a minimum, date, time and duration of the incident, the estimated resultant emissions, and any corrective measures taken. The records shall be in a permanent form suitable for inspection, shall be made available upon request by the Department of Health, and shall be retained for at least three (3) years following the date of such records.

18. Steam production rates and hydrogen sulfide concentrations shall be measured to determine hydrogen sulfide emissions in pounds per hour. A sodium hydroxide treatment mole ratio of 4 to 1 ($NaOH/H_2S$) will be used initially and the abatement efficiency monitored. The optimum mole ratios will be determined during the hydrogen sulfide abatement operations. A specific chemical treatment plan shall be submitted to the Department of Health prior to the commencement of flow testing. A copy of the plan shall be maintained at the site at all times and supervisory personnel shall be aware of its provisions at all times.

19. The permittee shall promptly notify the Department of Health should any toxic emissions be encountered of public health concern and where dispersion into the ambient air was the mitigative action.

20. The permittee shall perform once on each well, testing and analyses for all of the following constituents of the steam condensate, steam, particulates and/or gases emanating from each well:

STEAM CONDENSATE/TOTAL STEAM	GAS PHASE
Benzene	Benzene
Ammonium (Total)	Hydrogen Sulfide
Arsenic	Ammonia
Lead	Radon 222 and daughters
Cadmium	Mercury Vapor
Bicarbonate and Carbonate	Methane
Sulfates	

STEAM CONDENSATE/TOTAL STEAM	GAS PHASE
Chlorides	Non-Methane Hydrocarbons
Nitrates	Carbon dioxide
Boron (Total)	Sulfur dioxide
Hydrogen Sulfide (Total)	NESHAPS - pollutants as requested
Fluorides (Total)	
Total Sulfur	
Mercury (Total)	
pH	
Total Dissolved Solids	
Total Suspended Solids	
Percent Noncondensibles	

21. The drilling rig diesel engine generators and pumps shall be fired only on diesel fuel oil no. 2 with a maximum sulfur content not to exceed 0.5 percent by weight. The permittee shall maintain records on the total amount of fuel oil consumed by all the diesel engines for the drilling of each well. The total gallons of fuel oil consumed shall be submitted to the Department of Health at the completion of each well.

22. Unabated well venting shall be allowed only after the permittee has checked with the National Weather Service and is assured of meteorological conditions appropriate for good dispersion and minimal air quality impact. In no case shall the well venting commence if the average wind speed at the well site is less than 4 meters per second. Prior to well venting, the Department must be informed in writing a minimum of two (2) days prior to commencement and so concur. The public shall be notified a minimum of 24-hours in advance by notices in the newspapers of general circulation in Hawaii County. In addition, the permittee shall make a reasonable effort to notify all residents living within 3,500 feet of the permittee's property boundary a minimum of 24-hours in advance of open venting of each well and pipeline cleanout. In preparation for flow testing, each well shall be allowed to open vent only during the daytime and no more than a total of four (4) hours.

    In no case shall any well venting coincide with any pipeline cleanouts or well flow testing operations, or commence if the power plant emergency steam release facility is being utilized. If emergency steam releases from the power plant occur during the venting of any well, venting of that well shall be terminated as quickly as practical.

23. Should any of the air quality monitoring stations indicate an ambient hydrogen sulfide, one-hour average concentration greater than 100 ppb, the permittee shall take immediate action to the extent practical to reduce all wellfield emissions. Within four (4) hours of the exceedance, the permittee shall reduce all wellfield hydrogen sulfide emissions associated with wellfield construction operations, including but not limited to drilling, flow testing, venting, etc., by a minimum of 50 percent of the level during the event. Following the reduction in project emissions, if the monitoring stations still indicate ambient hydrogen sulfide concentrations in excess of 100 ppb (one-hour average), the permittee shall cease all drilling operations and shut-in all wells under construction, unless the permittee can conclusively show to the Department of Health that the project operations and emissions

are not contributing any impact to monitoring site. If the project emissions have been reduced, the permittee shall maintain the emissions at this reduced level until such time the Department of Health is assured that the resumption of full activity shall not result in another exceedance of the ambient level of 100 ppb (one-hour average).

The permittee shall submit to the Department of Health a written follow-up report within two (2) days of the occurrence. The report shall include the date, time and duration of the exceedance(s), the status of all project operations during the exceedance, the estimated project emissions and any other emission sources that may have contributed to the exceedance, and all corrective measures and actions to reduce project emissions to a minimum. Compliance with this notification provision shall not excuse or otherwise constitute a defense to any violation(s) of this permit or of any law or regulations.

24. The drilling, flow testing, and venting operations of any of the fourteen (14) geothermal exploratory/developmental wells shall not cause or contribute to an exceedance of the hydrogen sulfide ambient level of 100 ppb on a one-hour average at or beyond the project boundary.

25. The permittee may be required to install a control system acceptable to the Department of Health for the rapid throttling of steam flow and well shut-in on each developmental well prior to the well being connected to a resource distribution system. The requirement for a control system may be so specified in the subsequent Permit to Operate.

26. To prevent well blowouts, the permittee shall employ good drilling practices with proper blowout prevention equipment and experienced personnel in the drilling of the exploratory/developmental wells. Drilling supervisors shall be certified in blowout prevention at a minimum of once every two years by a recognized training center. In the unlikely event of a well blowout, the permittee shall immediately proceed with measures to kill or gain control of the well and notify the Department of Health.

    The permittee shall submit to the Department of Health a written report within five (5) days of the blowout. The report shall include, as a minimum, the probable cause of the blowout, the actions that have or will be taken, the estimated time before the well is controlled, an analysis of the air quality impact from the unabated emissions, and a monitoring plan to determine the actual air quality impact resulting from the blowout. A status report shall be submitted to the Department of Health on a weekly basis until such time the control of the well is established.

27. During those periods of normal power plant and wellfield operation, the combined emissions of hydrogen sulfide from the 25 MW geothermal power plant and associated wellfield shall not cause an increase in the ambient hydrogen sulfide concentration in excess of 5 ppb (one-hour average) above background at or beyond the project boundary. During those periods when geothermal well drilling, well flow testing, or emergency steam release may be occurring, whether separately, in any combination, or whether in combination with periods of normal power plant or wellfield operation, the combined emissions of hydrogen sulfide from these sources shall not cause an increase in the ambient hydrogen sulfide concentration in excess of 25 ppb (one-hour average) above background at or beyond the project boundary.

28. For any ambient hydrogen sulfide concentration in excess of 5 ppb (one-hour average) above background as indicated by any air quality monitoring station, the permittee has the burden of proving that operation of the 25 MW geothermal power plant and wellfield did not cause the hydrogen sulfide impact in excess of 5 ppb (one-hour average), or proving that the power plant or wellfield had experienced an operational upset, equipment failure, malfunction or was otherwise not operating normally. For any ambient hydrogen sulfide concentration in excess of 25 ppb (one-hour average) above background as indicated by any air quality monitoring station, the permittee has the burden of proving that operation of the 25 MW geothermal power plant and wellfield did not cause the hydrogen sulfide concentration in excess of 25 ppb (one-hour average), or proving that the measured impact occurred during the vertical venting of a geothermal well or cleanout of the steam production pipelines.

CERTIFIED MAIL
RETURN RECEIPT REQUESTED

February 6, 1990

90-A51
File #834

Mr. Maurice A. Richard
Regional Development Manager
Puna Geothermal Venture
101 Aupuni Street, Suite 1014-B
Hilo, Hawaii 96720

Dear Mr. Richard:

Subject: Authority to Construct (ATC) No. A-834-796
Application for ATC No. A-834
Expiration Date: February 1, 1992

An Authority to Construct in accordance with Administrative Rules, Title 11, Chapter 60, is hereby issued to Puna Geothermal Venture for a 25 MW Geothermal Power Plant located at TMK: 1-4-01:2 and 1-4-01:19, Kilauea Lower East Rift Zone, Puna, Hawaii. The issuance of this permit is based on the plans, specifications, and additional information that you submitted as part of your application dated March 24, 1989 and the subsequent information submitted on June 9, 1987.

The Authority to Construct is issued subject to the conditions set forth in Attachments I and II.

Also enclosed is Form AS-P-3, Application for Permit to Operate a Facility. Please submit this application with the applicable filing fee sixty (60) days before the end of construction. In addition, you must submit to the Department in writing the notification of completion of construction. The Authority to Construct must remain in effect until the Permit to Operate is granted or denied.

Very truly yours,

JOHN C. LEWIN, M.D.
Director of Health

Enclosures
cc: DHSA, Hawaii

ATTACHMENT I. STANDARD CONDITIONS OF AUTHORITY TO CONSTRUCT, NO. A-834-796
APPLICATION NO. A-834
POWER PLANT

This permit is granted in accordance with the State of Hawaii Administrative Rules, Title 11, Chapter 60, Air Pollution Control, and is subject to the following standard conditions:

1. This permit is non-transferable from person to person, from place to place, or from one piece of equipment to another.

2. This permit is automatically void if construction has not begun within one year of the date of issuance or if the work involved is suspended for one year or more.

3. This permit is automatically void when a Permit to Operate is issued or denied.

4. The facility covered by this permit shall be constructed as specified in the application for Authority to Construct. There shall be no deviation unless additional or revised plans are submitted to and approved by the Department.

5. This permit is not a guarantee that the facility will receive a Permit to Operate at the end of the construction period, nor does it absolve the holder from the responsibility for the consequences of non-compliance with all Rules, Regulations, and Orders of the Department.

6. This authority, (a) shall not in any manner affect the title of the premises upon which the equipment is to be located, (b) does not release the permittee from any liability for any loss due to personal injury or property damage caused by, resulting from or arising out of the design, installation, maintenance, or operation of the proposed equipment, (c) does not release the permittee from compliance with other applicable statutes of the State of Hawaii, or with applicable local laws, regulations, or ordinances, and (d) in no manner implies or suggests that the Department, or its officers, agents, or employees, assumes any liability, directly or indirectly, for any loss due to personal injury or property damage caused by, resulting from or arising out of the design, installation, maintenance, or operation of the proposed equipment.

7. The Department is to be notified promptly in writing upon completion of the construction or installation of any equipment for which an Authority to Construct has been issued.

8. The operation of this equipment is sanctioned by this Authority to Construct provided that the permittee has completed the following:

    (a) Submittal of written notification of completion of construction or installation to the Department;

    (b) Submittal of Permit to Operate Application, Form AS-P-3, to the Department; and

    (c) Adherence to all applicable "special conditions" as included in the Authority to Construct.

ATTACHMENT II. SPECIAL CONDITIONS OF AUTHORITY TO CONSTRUCT, NO. A-834-796
APPLICATION NO. A-834
POWER PLANT

In addition to the standard conditions of the Authority to Construct, this permit is subject to the following special conditions:

1. The permit conditions prescribed herein may at any time be revised by the Department of Health to conform to any Federal or State promulgated air quality rules on geothermal facilities.

2. The total fugitive isopentane emissions from all ten (10) Ormat Energy Converter (OEC) modules shall not exceed 0.4 lbs/hr or exceed 1000 ppm from any seal, flange, valve or any other fugitive emission point when measured from a distance of two (2) inches from the point. The permittee shall perform measurements on all fugitive isopentane emission points, as a minimum, on a weekly basis. The permittee shall take immediate corrective actions upon identifying any isopentane emissions in excess of 1000 ppm when measured from a distance of two (2) inches.

3. Records shall be maintained on all isopentane emission measurements, the amount of gallons of isopentane purchased, the amount of isopentane transferred to and from the OEC modules, and the amount of isopentane released to the atmosphere. The records shall be in a permanent form suitable for inspection, shall be made available upon request by the Department of Health, and shall be retained for at least three (3) years following the date of such records. A report on the amount of isopentane released to the atmosphere shall be submitted to the Department of Health on an annual basis.

4. The geothermal fluids injection system shall include at least two (2) geothermal injection wells, a spare fluid pump, and a spare noncondensable gas compressor. The backup injection system equipment shall be maintained in good operating condition at all times and shall be utilized immediately upon identification of any malfunctioning equipment.

   In the event of an equipment malfunction or upset condition which results in a situation where the two geothermal injection wells are not capable of handling the total geothermal resource being utilized by the power plant, the power plant production and the associated geothermal resource being used shall be immediately reduced accordingly to the handling capacity of the two injection wells.

5. The diesel engine generator and the diesel firewater pump shall be fired only on diesel fuel oil no. 2 with a maximum sulfur content not to exceed 0.5% by weight.

6. Pipeline cleanouts shall be allowed only after the permittee has checked with the National Weather Service and is assured of meteorological conditions appropriate for good dispersion and minimal air quality impact. In no case shall any pipeline cleanout commence if the average wind speed at the pipeline exhaust site is less than four (4) meters per second. In no case shall any pipeline cleanout coincide with any well venting, well flow testing, or well drilling with aerated water or aerated mud. Prior to any pipeline cleanout, the Department of Health must be informed in writing, a minimum of two (2) days prior to commencement and so concur. The public shall be notified a minimum of 24-hours in advance by notices in the newspapers of general circulation in Hawaii County. In addition, the permittee shall make a reasonable effort to notify all residents living within 3,500 feet of the permittee's property

boundary a minimum of 24-hours in advance of any pipeline cleanout. Each pipeline cleanout shall not exceed 20 minutes in duration and shall occur only in the daytime.

7. The permittee shall install, operate, and maintain a minimum of one (1) meteorological and three (3) air quality monitoring stations. The monitoring stations required in any permit for the wellfield may be used towards fulfilling this requirement. Prior to the commencement of construction, the permittee shall submit for the Department of Health's approval the siting of the air quality and meteorological monitoring stations. The air quality and meteorological monitoring stations shall be fully operational prior to the commencement of plant operations. The permittee shall maintain a file of all measurements, including the monitoring system performance evaluations; calibration checks; and adjustments and maintenance performed on the system or devices. The measured data shall meet U.S. EPA capture requirements and quality assurance guidelines. As a minimum, a quality assurance check shall be conducted on each monitoring station every-other-day.

   The air quality monitors shall be equipped with an alarm or acceptable equivalent system that will immediately notify the permittee of ambient hydrogen sulfide concentrations in excess of 25 ppb and 100 ppb on a one-hour average. The permittee shall immediately notify the Department of Health and the Hilo District Health Office of any exceedance above 100 ppb.

   Two (2) copies of the data file in a format acceptable to the Department of Health shall be submitted on an annual basis. The data file shall be in a format that can be utilized by a personal computer for ready extraction of data. The air quality and meteorological data shall be summarized and submitted monthly in writing to the Department of Health. Additional information on the monitoring stations and on the data collected shall be submitted upon request by the Department of Health.

8. At the discretion of the Director of Health the permittee may at any time be required to install, operate, and maintain additional air quality and meteorological monitoring stations, but only after due notice to the permittee on the reasons for the proposed change and providing the permittee an opportunity to respond within seven (7) days.

9. All access roads into the permittee's property shall be limited to authorized personnel only. Twenty-four hour staffing shall be in place during plant operations.

10. The emergency steam release facility, consisting of two (2) rock mufflers, chemical storage tank(s) and associated equipment, shall be installed, maintained, and be fully operational prior to commencement of plant operations. Each rock muffler shall be capable of handling a steam flow rate of 570,000 lbs/hr or 100 percent of the total power plant steam flow, whichever is greater.

11. The emergency steam release facility shall only be utilized under one or more of the following conditions:

    a) Failure of the electrical transmission lines out of the power plant or some incident that tripped all the steam turbines and OEC units;

b) Complete upset of the geothermal fluid injection system;

c) Pressure in the steam lines exceeds safety design set points; or

d) Any upset situation which would otherwise result in a release of unabated steam to the atmosphere.

12. The emergency steam release facility shall be equipped and maintained at all times with a minimum three-day operating storage capacity of sodium hydroxide. The chemical abatement system shall operate automatically when steam is released through the rock muffler(s). The hydrogen sulfide concentrations shall be continuously monitored both downstream and upstream of the chemical injection point. A sodium hydroxide treatment mole ratio of 4 to 1 ($NaOH/H_2S$) will be used initially and the abatement efficiency monitored. The optimum mole ratios will be determined during the hydrogen sulfide abatement operations.

Upon utilizing the emergency steam release facility, the permittee shall take immediate action to the extent practical to reduce the steam flow and perform the necessary corrective actions. The steam flow rate shall be reduced, as a minimum, to 50 percent of full flow within four (4) hours after initiating the use of the emergency steam release facility.

13. The permittee shall immediately notify the Department of Health of any operational upsets, equipment failure or malfunction which would allow an increase in the emissions of hydrogen sulfide, particulate matter or isopentane. In addition, a written report shall be submitted to the Department of Health within five (5) days of the occurrence. The report shall include a description of the malfunctioning equipment or abnormal operation, the date of the initial failure, the estimated resultant emissions, time and duration of the event, and the methods utilized to restore normal operations. Compliance with this notification provision shall not excuse or otherwise constitute a defense for any violation(s) of this permit, law, rule or order which results from the operational upset, equipment failure or malfunction.

14. The permittee shall maintain a 24-hour telephone service to accept calls concerning this Authority to Construct. This telephone number must be fully operational prior to commencement of construction.

15. Should any of the air quality monitoring stations indicate an ambient hydrogen sulfide, one-hour average concentration greater than 100 ppb, the permittee shall take immediate action to the extent practical to reduce all power plant emissions. Within four (4) hours of the exceedance, the permittee shall terminate all power plant activities not associated with normal power plant operations and contributing to hydrogen sulfide emissions. Following the reduction in project emissions, if the monitoring stations still indicate ambient hydrogen sulfide concentrations in excess of 100 ppb (one-hour average), the permittee shall curtail the power plant operations, unless the permittee can conclusively show to the Department of Health that the project operations and emissions are not contributing any impact to monitoring site. If the ambient hydrogen sulfide concentration is below 100 ppb (one-hour average) after the project emissions have been reduced, the permittee shall maintain the emissions at

this reduced level until such time the Department of Health is assured that the resumption of full activity shall not result in another exceedance of the ambient level of 100 ppb (one-hour average).

The permittee shall submit a written report to the Department of Health within two (2) days of the occurrence. The report shall include the date, time and duration of the exceedance, the estimated project emissions and any other emission sources that may have contributed to the exceedance, and all corrective measures and actions taken to reduce project emissions to a minimum. Compliance with this notification provision shall not excuse or otherwise constitute a defense for any violation(s) of this permit, law, rule or order.

16. The operation of the 25 MW geothermal power plant during periods of operational upsets, equipment failure or malfunctions shall not cause or contribute to an exceedance of the hydrogen sulfide ambient level of 100 ppb on a one-hour average at or beyond the project boundary.

17. During those periods of normal power plant and wellfield operation, the combined emissions of hydrogen sulfide from the 25 MW geothermal power plant and associated wellfield shall not cause an increase in the ambient hydrogen sulfide concentrations in excess of 5 ppb (one-hour average) above background at or beyond the project boundary. During those periods when geothermal well drilling, well flow testing, or emergency steam release may be occurring, whether separately, in any combination, or whether in combination with periods of normal power plant or wellfield operation, the combined emissions of hydrogen sulfide from these sources shall not cause an increase in the ambient hydrogen sulfide concentration in excess of 25 ppb (one-hour average) above background at or beyond the project boundary.

18. For any ambient hydrogen sulfide concentrations in excess of 5 ppb (one-hour average) above background as indicated by any air quality monitoring station, the permittee has the burden of proving that operation of the 25 MW geothermal power plant and wellfield did not cause the hydrogen sulfide impact in excess of 5 ppb (one-hour average), or proving that the power plant or wellfield had experienced an operational upset, equipment failure, malfunction or as otherwise not operating normally. For any ambient hydrogen sulfide concentration in excess of 25 ppb (one-hour average) above background as indicated by any air quality monitoring station, the permittee has the burden of proving that operation of the 25 MW geothermal power plant and wellfield did not cause the hydrogen sulfide concentration in excess of 25 ppb (one-hour average), or proving that the measured impact occurred during the vertical venting of a geothermal well or cleanout of the steam production pipelines.

19. During normal power plant operations, the hydrogen sulfide emissions from the 25 MW geothermal power plant shall not exceed one pound per hour (three-hour average). During periods of malfunction or regularly scheduled maintenance, best available control technology shall be applied for the hydrogen sulfide emissions.

20. The Department of Health may at any time with reasonable cause, request the permittee to install, operate, and maintain emission monitors to continuously measure

and record the hydrogen sulfide and isopentane emissions at any specified location in the power plant.

IN THE DEPARTMENT OF HEALTH

STATE OF HEALTH

PUNA GEOTHERMAL VENTURE)
25 MW GEOTHERMAL POWER PLANT AND WELLFIELD)
STATE AUTHORITY TO CONSTRUCT PERMITS)
REGULATING THE EMISSIONS OF AIR POLLUTANTS)
)

DOCKET NO. 89-EP-PA-13
HEARING OFFICER'S REPORT

HEARING OFFICER'S REPORT

Public hearings were conducted on November 7 and 8, 1989 at the Kailua-Kona Library, 75-138 Hualalai Road, Kailua-Kona, and UH-Hilo, Campus Center Activities Building, Rooms 306-307, 523 W. Lanikaula Street, Hilo, Hawaii, respectively. The purpose of the hearings was to consider and accept testimonies on Two Draft Permits, Regulating the Emissions of Air Pollutants, for the Puna Geothermal Venture's proposed construction of a 25 MW Geothermal Power Plant and Wellfield. The notice announcing the public hearings appeared in the Honolulu Advertiser, West Hawaii Today, and Hawaii Tribune Herald on October 6, 1989. Public comments and testimonies were accepted from the time of the notice until November 15, 1989.

FINDINGS OF FACT

1. Puna Geothermal Venture proposes to construct a 25 MW (net) geothermal power plant at Kilauea Lower East Rift Zone, Puna, Hawaii.
2. Puna Geothermal Venture proposes to construct fourteen (14) geothermal wells to supply and support the initial power plant operations.
3. The power plant consisting essentially of 10 integrated modular generating units, injection wells, air-cooled condensers, moisture separators, and vaporizers, is designed to re-inject all geothermal fluids produced back into the reservoir.
4. The power plant will incorporate an emergency steam release facility consisting of two (2) rock mufflers and caustic injection for utilization during upset conditions.

5. Puna Geothermal venture shall install, maintain, and ope[illegible] as a minimum, three (3) air quality monitoring stations and one meteorological monitoring station.

6. During normal operations, the power plant shall not cause an increase in the ambient hydrogen sulfide concentrations in excess of 5 ppb (one-hour average) above background.

PARTICIPATING CITIZENS

The Department of Health received written testimonies from the following individuals:

Name	Representing
Roger Ulveling	Director of Business & Economic Development
Robert Petricci	Leilani Community Association
Russell Kokubun	County of Hawaii
Karl Kirkendall	Self
Melissa Kirkendall	Self
R.W. Salzer	Self
Michael La Plante	Self
Greg Plescia	Self
Ron Phillips	Puna Community Council
Steve Slater	Self
Jane Hedtke	Kapoho Community Association
Jennifer Perry	Kapoho Grown
Steve Phillips	Self
Anne Wheelock	Self
Margaret McGuire	Self
Lawrence Jones	Self
Nelson Ho	Sierra Club
James Morrow	American Lung Association of Hawaii
Bonnie Gold	Self
Jette Slater	Self
Steven Moser	Self

WRITTEN TESTIMONIES

During the public comment period and at the hearing, the Department of Health received numerous comments on the proposed project and two Draft Permits. A brief description of the written comments received and the Department of Health's responses are attached.

REQUEST FOR CONTESTED CASE HEARING

In addition to the written comments, numerous petitions were filed with the Department of Health requesting a contested case hearing. The petitions and requests were referred to the Department of the Attorney General for review, where it was determined that there was no legal mandate to grant such a request under Section 342B-4, Hawaii Revised Statutes.

CONCLUSION/RECOMMENDATIONS

This hearing officer feels that the concerns and issues received during the public hearing and the public comment period were addressed by the Clean Air Branch staff. Additionally, the conditions imposed in the ATC permits enables the Department to monitor construction activities to ensure the protection of public health. Therefore, this hearing officer recommends adoption of the ATC permits.

DATED: Honolulu, Hawaii 2-6-90

James K. Ikeda

JAMES K. IKEDA
Hearing Officer

JOHN WAIHEE
GOVERNOR OF HAWAII

STATE OF HAWAII
DEPARTMENT OF LAND AND NATURAL RESOURCES
COMMISSION ON WATER RESOURCE MANAGEMENT
P. O. BOX 621
HONOLULU, HAWAII 96809

January 9, 1990

MEMORANDUM

TO: Dr. Bruce Anderson, Deputy Director
Department of Health

FROM: Manabu Tagomori, Deputy Director
Commission on Water Resource Management

SUBJECT: Review of Puna Geothermal Venture's Underground Injection Control (UIC) Permit Application No. UH-1529

Thank you for the opportunity to review and comment on the UIC Permit application submitted by Puna Geothermal Venture (PGV).

The Department of Land and Natural Resources (DLNR) has no major objections to PGV's proposal to re-inject geothermal fluids into the geothermal reservoir, but would like to offer the following comments:

1) Based on PGV's proposal to re-inject geothermal fluids and non-condensable gases into the geothermal reservoir, and in response to community concerns regarding potential impacts to the ground water aquifer downgradient from the project site, we recommend that if a water supply well is to be developed, it be strategically placed within the project area to maximize its use as a monitor well. Proper placement of the proposed well relative to existing wells in the area will allow for better ground-water monitoring.

   The applicant should be informed that under Chapter 13-168, HAR, a well construction permit, a pump installation permit, and a well completion report will be required for the construction of the water well.

2) No DLNR permit is required for those wells specifically dedicated and drilled for injection purposes; however, the conversion of any existing geothermal production well into an injection well (i.e. Alternative 1 - wells not specifically drilled for injection purposes) will require a well modification permit from DLNR.

3) Pursuant to HAR, Chapter 13-183, all geothermal wells must be cased in a manner to provide adequate anchorage for blowout-prevention equipment that will protect ground-water resources and the general environment. Also, permanent wellhead completion equipment and all casing strings must provide for adequate well pressure control and operational safety. Our review of the two injection well designs (Alternative 1 and Alternative 2) identified in PGV's UIC application indicates that the proposed casings meet the requirements set forth in Section 13-183-71.

During the setting of the casing, sufficient cement should be used to exclude overlying formation fluids from the injection zone and to prevent movement of fluids behind the casing into zones that contain ground water. Furthermore, all cement should contain a high temperature resistant admixture.

4) We also recommend that casing strings be pressure-tested after cementing and before commencing other operations on the well. Test pressures should be applied and monitored for a period of 30 minutes. A drop of more than ten percent of the pressure may be indicative of a defective casing or cement job.

5) Surveys should be required for all injection wells to determine deviations from the vertical and to establish the location of the intended zone of injection. Well deviation surveys should be filed with DLNR.

6) In addition, within six months after completion/modification of any well, the operator must file with DLNR the following well reports: a) drilling log and core report; b) well history report; c) well summary report; and (d) other supplemental information related to the injection operations.

7) The operator of any injection well must also file monthly reports of re-injection data, including quantity and chemical composition of fluids injected and any changes in injection pressures which may indicate that the injected fluids are no longer confined to the intended zone of injection.

8) As part of the monitoring plan, PGV should acquire adequate environmental baseline data prior to commencement of injection operations. Monitoring for potential impacts associated with such activity should include periodic water sampling and regular inspections of the injection facility.

9) Lastly, all work pertaining to the lands and permittee's operations should be performed in accordance with our Department's Administrative Rules (Chapters 13-183 and 13-168) and all other applicable Federal, State, and County laws,

ordinances, and regulations, including all water and air pollution control laws relating to the environment.

Thank you for this opportunity to comment on the subject application. Should you have any questions, please contact George Matsumoto at Ext. 7619.

for George S. Matsumoto
MANABU TAGOMORI
Deputy Director

DN:fc

JOHN WAIHEE
GOVERNOR OF HAWAII

STATE OF HAWAII
DEPARTMENT OF HEALTH
P. O. BOX 3378
HONOLULU, HAWAII 96801

JOHN C. LEWIN, M.D.
DIRECTOR OF HEALTH

18 A8 : 39

In reply, please refer to:
EPHSD

November 30, 1989

Mr. Manabu Tagomori
Deputy Director
Commission on Water Resource Management
Department of Land & Natural Resources
P.O. Box 373
Honolulu, Hawaii 96809

Dear Mr. Tagomori:

SUBJECT: PUNA GEOTHERMAL VENTURE PROJECT
UNDERGROUND INJECTION CONTROL (UIC)
UIC APPLICATION NO. UH-1529

Enclosed is an application for an Underground Injection Control permit to operate injection wells for the proposed geothermal project. We would appreciate any comments you may have concerning this project's injection wells in regards to their impact on underground sources of drinking water and hydrogeologic conditions of the area. We are also interested in any geothermal permit conditions that may be generated from your office that could apply to the UIC permit.

For your information, the two primary areas of concern to us are: 1) a long-term geothermal well casing monitoring plan, and 2) a long-term groundwater monitoring plan. Your comments will be used to determine the issuance of a UIC permit for this project and other requirements that should be imposed on the permittee for proper subsurface injection, if a permit is granted.

If you have any questions concerning this subject, please contact Chauncey Hew at the Safe Drinking Water Branch at telephone 543-8258.

Thank you for your assistance.

Sincerely,

Bruce S. Anderson

BRUCE S. ANDERSON, Ph.D.
Deputy Director for
Environmental Health

CH:la
Enclosure: UIC Application No. UH-1529

ORMAT®

June 26, 1989
Reference No. 89238

Mr. Chauncey Hew
Drinking Water Program
Department of Health
P.O. Box 3378
Honolulu, Hawaii 96801

Subject: Application for Underground Injection Control (UIC) Permit from the Puna Geothermal Venture (PGV) Project

Dear Mr. Hew:

Pursuant to Administrative Rules, Title 11, Chapter 23 of the Department of Health, attached are three (3) copies of the Application for a UIC Permit for the PGV Project. Also attached is a check in the amount of $100.00 for the filing fee.

PGV plans to construct and operate the 25 MW PGV Project in the Puna District of the Island of Hawaii. The project will drill geothermal wells within a dedicated 500-acre area, use the produced geothermal fluid to generate electricity for sale to the Hawaii Electric Light Company for use on the Island of Hawaii, and inject all the project geothermal fluids back into the geothermal reservoir. Since the project will use injection wells, it will require a UIC permit from the Drinking Water Section of the State of Hawaii Department of Health.

This UIC permit application is being filed for a well system classified as Class V, Subclass B injection wells, which applies to "injection wells which inject non-polluting fluids into any geohydrologic formation, including non-exempt aquifers." PGV will be injecting the produced geothermal fluid into the zone below 4,000 feet, back into the same geothermal reservior from which it was withdrawn. Other than the loss of heat, which will be used to generate electricity, the geothermal fluids will to contain the same constituents as the geothermal reservoir. PGV has proposed a casing program using premium grade materials and cements to prevent leakage of injected fluids from the casing to the upper groundwater aquifer, a groundwater aquifer which is already influenced by the natural leakage of geothermal fluids from the zone below 4,000 feet.

PUNA GEOTHERMAL VENTURE

☐ 101 Aupuni Street Suite 1014-B, Hilo, Hawaii 96720 • Telephone (808) 961-2184 • Facsimile (808) 961-3531
☐ 610 East Glendale Ave., Sparks, Nevada 89431-5811 • Telephone (702) 356-9111 • Facsimile (702) 356-9125

The UIC permit is a two-step application process, and this application is for the initial construction stage. As such, it contains the information required under Sections 11-23-60(a)(1) through 11-23-60(a)(15) of the existing UIC regulations.

We appreciate your cooperation in preparing this application and offer our full assistance in your timely review and approval of this UIC permit.

Sincerely,

Maurice A. Richard
Puna Geothermal Venture
Hawaii Regional
Development Manager

Attachments

cc:
D. Carey, EMA w/attachments

MAR/ci

CERTIFIED MAIL
<u>RETURN RECEIPT REQUESTED</u>

A0962NH
File #833

Mr. Maurice A. Richard
Regional Development Manager
Puna Geothermal Venture
101 Aupuni Street, Suite 1014-B
Hilo, Hawaii 96720

Dear Mr. Richard:

Subject: Authority to Construct (ATC) No. A-833-XXX
Application for ATC No. A-833
Expiration Date: (will be valid for 2 years)

An Authority to Construct in accordance with Administrative Rules, Title 11, Chapter 60, is hereby issued to Puna Geothermal Venture for Fourteen (14) Geothermal Exploratory/Developmental Wells located at TMK: 1-4-01:2, 1-4-01:3, 1-4-01:58 and 1-4-01:19, Kilauea Lower East Rift Zone, Puna, Hawaii. The issuance of this permit is based on the plans, specifications, and additional information that you submitted as part of your application dated March 24, 1989 and the subsequent information submitted on June 9, 1989.

Although the Authority to Construct application is for the construction of 30 geothermal wells over the life of the project, the subject Authority to Construct permit authorizes the construction of only 14 geothermal wells which have been deemed necessary to initially supply and support the power plant operating at maximum capacity. Authority to Construct application(s) for additional geothermal wells should be submitted as the needs are identified.

The Authority to Construct is issued subject to the conditions set forth in Attachments I and II.

Also enclosed is Form AS-P-3, Application for Permit to Operate a Facility. Please submit this application with the <u>applicable filing fee</u> sixty (60) days prior to each well being connected and becoming a part of a distribution system which supplies geothermal resource to a power plant or facility. In addition, you must submit to the Department <u>in writing</u> the notification of completion of construction. The Authority to Construct must remain in effect until the Permit to Operate is granted or denied for the fourteen (14) geothermal exploratory/developmental wells.

Very truly yours,

JOHN C. LEWIN, M.D.
Director of Health

Enclosures
cc: PIE
DHSA, Hawaii

ATTACHMENT I. STANDARD CONDITIONS

This permit is granted in accordance with the State of Hawaii Administrative Rules, Title 11, Chapter 60, Air Pollution Control, and is subject to the following standard conditions:

1. This permit is non-transferable from person to person, from place to place, or from one piece of equipment to another.

2. This permit is automatically void if construction has not begun within one year of the date of issuance or if the work involved is suspended for one year or more.

3. This permit is automatically void when the Permit to Operate is issued or denied for all fourteen (14) exploratory/developmental wells.

4. The facility covered by this permit shall be constructed as specified in the application for Authority to Construct. There shall be no deviation unless additional or revised plans are submitted to and approved by the Department.

5. This permit is not a guarantee that the facility will receive a Permit to Operate at the end of the construction period, nor does it absolve the holder from the responsibility for the consequences of non-compliance with all Rules, Regulations, and Orders of the Department.

6. This authority, (a) shall not in any manner affect the title of the premises upon which the equipment is to be located, (b) does not release the permittee from any liability for any loss due to personal injury or property damage caused by, resulting from or arising out of the design, installation, maintenance, or operation of the proposed equipment, (c) does not release the permittee from compliance with other applicable statutes of the State of Hawaii, or with applicable local laws, regulations, or ordinances, and (d) in no manner implies or suggests that the Department, or its officers, agents, or employees, assumes any liability, directly or indirectly, for any loss due to personal injury or property damage caused by, resulting from or arising out of the design, installation, maintenance, or operation of the proposed equipment.

7. The Department is to be notified promptly in writing upon completion of the construction or installation of any equipment for which an Authority to Construct has been issued.

ATTACHMENT II. SPECIAL CONDITIONS

In addition to the standard conditions of the Authority to Construct, this permit is subject to the following special conditions:

1. The permit conditions prescribed herein may at any time be revised by the Department of Health to conform to any Federal or State promulgated air quality rules on geothermal facilities.

2. This Authority to Construct is for fourteen (14) geothermal exploratory/developmental wells to be drilled in TMK: 1-4-01:2, 1-4-01:3, 1-4-01:58 and 1-4-01:19, Kilauea Lower East Rift Zone, Puna, Hawaii. Written notification must be submitted to and accepted by the Department of Health prior to commencement of construction of each well. Each notification shall include a drawing identifying the well location, the property boundary, access roads approaching and traversing the property, the location of the nearest residence, and the locations of the air quality monitoring stations. The status of all previous constructed wells shall be provided including a clear description of the measures taken to shut-in the well. Additional information may be requested of the permittee.

3. The Department of Health shall act on a Permit to Operate Application prior to any well approved under this permit being connected and becoming a part of a distribution system which supplies geothermal resource to a power plant or facility. Additional permit conditions may be included in the Permit to Operate.

4. No geothermal exploratory/developmental wells shall be located within 600 feet of the property boundary. If any federal, state or county permit or order stipulates a distance greater than 600 feet in which no geothermal wells can be located, the greater distance shall so apply.

5. The permittee shall install, operate, and maintain a minimum of one (1) meteorological and three (3) air quality monitoring stations. The monitoring stations required in any permit for the 25 MW power plant may be used towards fulfilling this requirement.

   Prior to the commencement of construction of each of the fourteen (14) wells, the permittee shall submit for the Department of Health's approval the siting of the air quality and meteorological monitoring stations. The air quality and meteorological monitoring stations shall be fully operational prior to the commencement of drilling operations. The permittee shall maintain a file of all measurements, including the monitoring system performance evaluations; calibration checks; and adjustments and maintenance performed on the system or devices. The measured data shall meet U.S. EPA capture requirements and quality assurance guidelines. At a minimum, a quality assurance check shall be conducted on each monitoring station every-other-day.

The air quality monitors shall be equipped with an alarm system or an acceptable equivalent system that will immediately notify the permittee of ambient hydrogen sulfide concentrations in excess of 139 micrograms per cubic meter of air on a one-hour average. The permittee shall immediately notify the Department of Health and the Hilo District Health Office of the exceedance.

Two (2) copies of the data file in a format acceptable to the Department of Health shall be submitted on an annual basis. The data file shall be in a format that can be utilized by a personal computer for ready extraction of data. The air quality and meteorological data shall be summarized and submitted monthly in writing to the Department of Health. Additional information on the monitoring stations and on the data collected shall be submitted upon request by the Department of Health.

6. At the discretion of the Director of Health, the permittee may at any time be required to install, operate, and maintain additional air quality and meteorological monitoring stations, but only after due notice to the permittee on the reasons for the proposed change and providing the permittee an opportunity to respond within seven (7) days.

7. The permittee shall notify the Department of Health in writing at least two (2) working days prior to the commencement, and within two (2) working days after the completion of the aerated mud or aerated water drilling, well venting, and flow testing operations, for each geothermal well.

8. Upon completion of flow testing operations, each geothermal well shall be shut-in or otherwise prevented from discharging to the atmosphere in accordance with appropriate standards of operation and maintenance and at no time be placed on continuous or standby bleed status.

9. Occasional flaring of excess hydrogen sulfide gas from the completed wells is prohibited unless necessary to insure well integrity or safety. Records shall be maintained on all flaring episodes, and shall include, as a minimum, the date, time and duration of the event, probable causes of the excess gas buildup, and the estimated emissions of hydrogen sulfide and sulfur dioxides. The records shall be in a permanent form suitable for inspection and shall be retained for at least three (3) years following the date of such records. The permittee shall submit a written report monthly to the Department of Health on the flaring episodes. If flaring occurs frequently or routinely, the permittee shall install, operate, and maintain ambient sulfur dioxide monitors at each air quality monitoring station and comply with all recordkeeping requirements in accordance with Special Condition No. 5.

10. All access roads into the property shall be limited to authorized personnel only. Twenty-four hour staffing shall be in place during construction.

11. The permittee shall have proper safety devices on-site at least three days

~~air~~
or drilling operations

prior to commencement of air drilling. A minimum of three breathing apparati shall be available at the site and maintained by a qualified person/contractor. Wind socks shall be placed at two opposite edges of the drill site and on the drill floor. At least one person with certified hydrogen sulfide training to respond to hydrogen sulfide emergency episodes shall be on-site at all times.

12. Hydrogen sulfide abatement equipment with a minimum of 3,000 gallons of sodium hydroxide shall be on the property prior to the initiation of flow testing operations. Chemical storage tanks shall be maintained with sodium hydroxide at all times with no less than a three-day operating supply.

13. The permittee shall monitor the hydrogen sulfide concentrations and emissions continuously by use of an electrochemical type sensor and recorder during the flow testing operations. If the abated hydrogen sulfide emission rate increases to eight and one-half (8.5) pounds per hour or more, the permittee shall cease operations and shut-in the well. The Department of Health shall be so notified and the problem corrected before testing operations can continue.

    During periods of equipment failure or malfunction which result in hydrogen sulfide emissions, the permittee shall apply best available control technology for the air emissions and shall so notify the Department of Health within one (1) hour of the occurrence. The permittee shall immediately take steps to correct the condition. If repairs cannot be accomplished within twenty-four (24) hours of the occurrence, the permittee shall cease operations and shut-in the well. Within five (5) days of the occurrence, a report shall be submitted to the Department of Health in accordance with Hawaii Administrative Rules, Section 11-60-14.

14. Wet chemical tests for the determination of the hydrogen sulfide concentrations shall be conducted and recorded on a daily basis during all phases of the flow testing operations.

15. The following data shall be recorded during the flow testing operations:

    a. At least four times per 24-hour period, hydrogen sulfide ppm upstream from the injection system.

    b. At least four times per 24-hour period, injection rate of sodium hydroxide.

    c. At least four times per 24-hour period, hydrogen sulfide emission rate (lbs/hr) and concentration (ppm) downstream, after chemical injection.

    d. Daily, zero and span check of hydrogen sulfide sensor.

e. Weekly, calibration check of hydrogen sulfide sensor.

f. Daily, the quantity of sodium hydroxide remaining in the abatement equipment storage tanks.

Additional entries will be made when significant changes in the resource occurs and when changes are made in injection rates of sodium hydroxide. The aforementioned daily records a., b., and c. shall also be reported daily to the Department of Health by telephone no later than noon of the following work day. The Department of Health may at any time request additional data or revise the frequency of this daily telephone reporting requirement.

The records shall be kept at the well location at all times during the drilling and flow testing operations and shall be made available upon request by the Department of Health or its duly authorized representative. Copies or summaries of the records shall be provided within a reasonable time upon request by the Department of Health. The records shall be retained for at least three years following the date of such records.

16. The permittee shall maintain a 24-hour telephone service to accept calls concerning this Authority to Construct. This telephone number must be operational prior to commencement of construction.

17. The permittee shall utilize mud drilling techniques to the extent possible during the well drilling operations. In no case shall air drilling be used in the construction of the geothermal well. The drilling with aerated mud or aerated water may be used in lieu of mud drilling, but should be minimized to the extent practical. Should any inadvertent releases of steam occur during the drilling operations, the drilling fluid weight shall be immediately increased to stop the steam flow. In no case shall any inadvertent steam releases exceed ten (10) minutes in duration in any one hour. If the inadvertent steam releases cannot be controlled by increasing the fluid weight or exceeds ten (10) minutes in duration, the permittee shall take immediate action to shut-in the well.

Records of each steam release incident shall be maintained and include as a minimum, date, time and duration of the incident, the estimated resultant emissions, and any corrective measures taken. The records shall be in a permanent form suitable for inspection, shall be made available upon request by the Department of Health, and shall be retained for at least three (3) years following the date of such records.

18. Steam production rates and hydrogen sulfide concentrations shall be measured to determine hydrogen sulfide emissions in pounds per hour. A sodium hydroxide treatment mole ratio of 4 to 1 (NaOH/H2S) will be used initially and the abatement efficiency monitored. The optimum mole ratios will be determined during the hydrogen sulfide abatement operations. A

specific chemical treatment plan shall be submitted to the Department of Health prior to the commencement of flow testing. A copy of the plan shall be maintained at the site at all times and supervisory personnel shall be aware of its provisions at all times.

19. The permittee shall promptly notify the Department of Health should any toxic emissions be encountered of public health concern and where dispersion into the ambient air was the mitigative action.

20. The permittee shall perform once on each well, testing and analyses for all of the following constituents of the steam condensate, steam, particulates and/or gases emanating from each well:

STEAM CONDENSATE/TOTAL STEAM	GAS PHASE
Benzene	Benzene
Ammonium (Total)	Hydrogen Sulfide
Arsenic	Ammonia
Lead	Radon 222 and daughters
Cadmium	Mercury Vapor
Bicarbonate and Carbonate	Methane
Sulfates	NonMethane Hydro-carbons
Chlorides	Carbon dioxide
Nitrates	Sulfur dioxide
Boron (Total)	NESHAPS - pollutants as requested
Hydrogen Sulfide (Total)	
Fluorides (Total)	
Total Sulfur	
Mercury (Total)	
pH	
Total Dissolved Solids	
Total Suspended Solids	
Percent Noncondensibles	

21. The drilling rig diesel engine generators and pumps shall be fired only on diesel fuel oil no. 2 with a maximum sulfur content not to exceed 0.5 percent by weight. The permittee shall maintain records on the total amount of fuel oil consumed by all the diesel engines for the drilling of each well. The total gallons of fuel oil consumed shall be submitted to the Department of Health at the completion of each well.

22. Unabated well venting shall be allowed only after the permittee has checked with the National Weather Service and is assured of meteorological conditions appropriate for good dispersion and minimal air quality impact. In no case shall the well venting commence if the average wind speed at the well site is less than 4 meters per second. Prior to well venting, the Department must be informed in writing a minimum of two (2) days prior to commencement and so concur. The public shall be notified a minimum of 24-hours in advance by notices in the newspapers of general circulation

in Hawaii County. In addition, the permittee shall make a reasonable effort to notify all residents living within 3,500 feet of the permittee's property boundary a minimum of 24-hours in advance of open venting of each well and pipeline cleanout. In preparation for flow testing, each well shall be allowed to open vent only during the daytime and no more than a total of four (4) hours.

In no case shall any well venting coincide with any pipeline cleanouts or well flow testing operations, or commence if the power plant emergency steam release facility is being utilized. If emergency steam releases from the power plant occur during the venting of any well, venting of that well shall be terminated as quickly as practical.

23. Should any of the air quality monitoring stations indicate an ambient hydrogen sulfide, one-hour average concentration greater than 139 micrograms per cubic meter of air, the permittee shall take immediate action to the extent practical to reduce all wellfield emissions. Within four (4) hours of the exceedance, the permittee shall reduce all wellfield hydrogen sulfide emissions associated with wellfield construction operations, including but not limited to drilling, flow testing, venting, etc., by a minimum of 50 percent of the level during the event. Following the reduction in project emissions, if the monitoring stations still indicate ambient hydrogen sulfide concentrations in excess of 139 micrograms per cubic meter (one-hour average), the permittee shall cease all drilling operations and shut-in all wells under construction, unless the permittee can conclusively show to the Department of Health that the project operations and emissions are not contributing any impact to monitoring site. If the project emissions have been reduced, the permittee shall maintain the emissions at this reduced level until such time the Department of Health is assured that the resumption of full activity shall not result in another exceedance of the ambient level of 139 micrograms per cubic meter (one-hour average).

    The permittee shall submit to the Department of Health a written follow-up report within two (2) days of the occurrence. The report shall include the date, time and duration of the exceedance(s), the status of all project operations during the exceedance, the estimated project emissions and any other emission sources that may have contributed to the exceedance, and all corrective measures and actions to reduce project emissions to a minimum. Compliance with this notification provision shall not excuse or otherwise constitute a defense to any violation(s) of this permit or of any law or regulations.

24. The drilling, flow testing, and venting operations of any of the fourteen (14) geothermal exploratory/developmental wells shall not cause or contribute to an exceedance of the hydrogen sulfide ambient level of 139 micrograms per cubic meter on a one-hour average.

25. The permittee may be required to install a control system acceptable to

the Department of Health for the rapid throttling of steam flow and well shut-in on each developmental well prior to the well being connected to a resource distribution system. The requirement for a control system may be so specified in the subsequent Permit to Operate.

26. To prevent well blowouts, the permittee shall employ good drilling practices with proper blowout prevention equipment and experienced personnel in the drilling of the exploratory/developmental wells. Drilling supervisors shall be certified in blowout prevention at a minimum of once every two years by a recognized training center. In the unlikely event of a well blowout, the permittee shall immediately proceed with measures to kill or gain control of the well and notify the Department of Health.

The permittee shall submit to the Department of Health a written report within five (5) days of the blowout. The report shall include, as a minimum, the probable cause of the blowout, the actions that have or will be taken, the estimated time before the well is controlled, an analysis of the air quality impact from the unabated emissions, and a monitoring plan to determine the actual air quality impact resulting from the blowout. A status report shall be submitted to the Department of Health on a weekly basis until such time the control of the well is established.

DRAFT: PGV-Power Plant
September 25, 1989

CERTIFIED MAIL
RETURN RECEIPT REQUESTED

A0961NH
File #834

Mr. Maurice A. Richard
Regional Development Manager
Puna Geothermal Venture
101 Aupuni Street, Suite 1014-B
Hilo, Hawaii 96720

Dear Mr. Richard:

Subject: Authority to Construct (ATC) No. A-834-XXX
Application for ATC No. A-834
Expiration Date: (will be valid for 2 years)

An Authority to Construct in accordance with Administrative Rules, Title 11, Chapter 60, is hereby issued to Puna Geothermal Venture for a 25 MW Geothermal Power Plant located at TMK: 1-4-01:2 and 1-4-01:19, Kilauea Lower East Rift Zone, Puna, Hawaii. The issuance of this permit is based on the plans, specifications, and additional information that you submitted as part of your application dated March 24, 1989 and the subsequent information submitted on June 9, 1987.

The Authority to Construct is issued subject to the conditions set forth in Attachments I and II.

Also enclosed is Form AS-P-3, Application for Permit to Operate a Facility. Please submit this application with the applicable filing fee sixty (60) days before the end of construction. In addition, you must submit to the Department in writing the notification of completion of construction. The Authority to Construct must remain in effect until the Permit to Operate is granted or denied.

Very truly yours,

JOHN C. LEWIN, M.D.
Director of Health

Enclosures
cc: PIE
DHSA, Hawaii

ATTACHMENT I. STANDARD CONDITIONS OF AUTHORITY TO CONSTRUCT, NO. A-834-XXX
APPLICATION NO. A-834

This permit is granted in accordance with the State of Hawaii Administrative Rules, Title 11, Chapter 60, Air Pollution Control, and is subject to the following standard conditions:

1. This permit is non-transferable from person to person, from place to place, or from one piece of equipment to another.

2. This permit is automatically void if construction has not begun within one year of the date of issuance or if the work involved is suspended for one year or more.

3. This permit is automatically void when a Permit to Operate is issued or denied.

4. The facility covered by this permit shall be constructed as specified in the application for Authority to Construct. There shall be no deviation unless additional or revised plans are submitted to and approved by the Department.

5. This permit is not a guarantee that the facility will receive a Permit to Operate at the end of the construction period, nor does it absolve the holder from the responsibility for the consequences of non-compliance with all Rules, Regulations, and Orders of the Department.

6. This authority, (a) shall not in any manner affect the title of the premises upon which the equipment is to be located, (b) does not release the permittee from any liability for any loss due to personal injury or property damage caused by, resulting from or arising out of the design, installation, maintenance, or operation of the proposed equipment, (c) does not release the permittee from compliance with other applicable statutes of the State of Hawaii, or with applicable local laws, regulations, or ordinances, and (d) in no manner implies or suggests that the Department, or its officers, agents, or employees, assumes any liability, directly or indirectly, for any loss due to personal injury or property damage caused by, resulting from or arising out of the design, installation, maintenance, or operation of the proposed equipment.

7. The Department is to be notified promptly in writing upon completion of the construction or installation of any equipment for which an Authority to Construct has been issued.

8. The operation of this equipment is sanctioned by this Authority to Construct provided that the permittee has completed the following:

   (a) Submittal of written notification of completion of construction or installation to the Department;

   (b) Submittal of Permit to Operate Application, Form AS-P-3, to the Department; and

   (c) Adherence to all applicable "special conditions" as included in the Authority to Construct.

ATTACHMENT II. SPECIAL CONDITIONS

In addition to the standard conditions of the Authority to Construct, this permit is subject to the following special conditions:

1. The permit conditions prescribed herein may at any time be revised by the Department of Health to conform to any Federal or State promulgated air quality rules on geothermal facilities.

9.6 lb/day

2. The total fugitive isopentane emissions from all ten (10) Ormat Energy Converter (OEC) modules shall not exceed 0.4 lbs/hr or exceed 1000 ppm from any seal, flange, valve or any other fugitive emission point when measured from a distance of two (2) inches from the point. The permittee shall perform measurements on all fugitive isopentane emission points, as a minimum, on a weekly basis. The permittee shall take immediate corrective actions upon identifying any isopentane emissions in excess of 1000 ppm when measured from a distance of two (2) inches.

3. Records shall be maintained on all isopentane emission measurements, the amount of gallons of isopentane purchased, the amount of isopentane transfered to and from the OEC modules, and the amount of isopentane released to the atmosphere. The records shall be in a permanent form suitable for inspection, shall be made available upon request by the Department of Health, and shall be retained for at least three (3) years following the date of such records. A report on the amount of isopentane released to the atmosphere shall be submitted to the Department of Health on an annual basis.

4. The geothermal fluids injection system shall include at least two (2) geothermal injection wells, a spare fluid pump, and a spare noncondensable gas compressor. The backup injection system equipment shall be maintained in good operating condition at all times and shall be utilized immediately upon identification of any malfunctioning equipment.

   In the event of an equipment malfunction or upset condition which results in a situation where the two geothermal injection wells are not capable of handling the total geothermal resource being utilized by the power plant, the power plant production and the associated geothermal resource being used shall be immediately reduced accordingly to the handling capacity of the two injection wells.

5. The diesel engine generator and the diesel firewater pump shall be fired only on diesel fuel oil no. 2 with a maximum sulfur content not to exceed 0.5% by weight.

6. Pipeline cleanouts shall be allowed only after the permittee has checked with the National Weather Service and is assured of meteorological conditions appropriate for good dispersion and minimal air quality impact. In no case shall any pipeline cleanout commence if the average wind speed at the pipeline exhaust site is less than four (4) meters per second. In no case shall any pipeline cleanout coincide with any well venting, well flow testing, or well drilling with aerated water or aerated mud. Prior to any pipeline cleanout, the Department of Health must be informed in writing, a minimum of two (2) days prior to commencement and so concur. The public shall be notified a minimum of 24-hours in advance by notices in the newspapers of general circulation in Hawaii County. In addition, the permittee shall make a reasonable effort to notify all residents living within 3,500 feet of the permittee's property boundary a minimum of 24-hours in advance of any pipeline cleanout. Each pipeline cleanout shall not exceed 20 minutes in duration and shall occur only in the daytime.

7. The permittee shall install, operate, and maintain a minimum of one (1) meteorological and three (3) air quality monitoring stations. The monitoring stations required in any permit for the wellfield may be used towards fulfilling this requirement. Prior to the commencement of construction, the permittee shall submit for the Department of Health's approval the siting of the air quality and meteorological monitoring stations. The air quality and meteorological monitoring stations shall be fully operational prior to the commencement of plant operations. The permittee shall maintain a file of all measurements, including the monitoring system performance evaluations; calibration checks; and adjustments and maintenance performed on the system or devices. The measured data shall meet U.S. EPA capture requirements and quality assurance guidelines. As a minimum, a quality assurance check shall be conducted on each monitoring station every-other-day.

   The air quality monitors shall be equipped with an alarm or acceptable equivalent system that will immediately notify the permittee of ambient hydrogen sulfide concentrations in excess of 139 micrograms per cubic meter of air on a one-hour average. The permittee shall immediately notify the Department of Health and the Hilo District Health Office of the exceedance.

   Two (2) copies of the data file in a format acceptable to the Department of Health shall be submitted on an annual basis. The data file shall be in a format that can be utilized by a personal computer for ready extraction of data. The air quality and meteorological data shall be summarized and submitted monthly in writing to the Department of Health. Additional information on the monitoring stations and on the data collected shall be submitted upon request by the Department of Health.

8. At the discretion of the Director of Health the permittee may at any time be required to install, operate, and maintain additional air quality and meteorological monitoring stations, but only after due notice to the permittee on the reasons for the proposed change and providing the permittee an opportunity to respond within seven (7) days.

9. All access roads into the permittee's property shall be limited to authorized personnel only. Twenty-four hour staffing shall be in place during plant operations.

10. The emergency steam release facility, consisting of two (2) rock mufflers, chemical storage tank(s) and associated equipment, shall be installed, maintained, and be fully operational prior to commencement of plant operations. Each rock muffler shall be capable of handling a steam flow rate of 570,000 lbs/hr or 100 percent of the total power plant steam flow, whichever is greater.

11. The emergency steam release facility shall only be utilized under one or more of the following conditions:

    a) Failure of the electrical transmission lines out of the power plant or some incident that tripped all the steam turbines and OEC units;

    b) Complete upset of the geothermal fluid injection system;

    c) Pressure in the steam lines exceeds safety design set points; or

    d) Any upset situation which would otherwise result in a release of unabated steam to the atmosphere.

12. The emergency steam release facility shall be equipped and maintained at all times with a minimum three-day operating storage capacity of sodium hydroxide. The chemical abatement system shall operate automatically when steam is released through the rock muffler(s). The hydrogen sulfide concentrations shall be continuously monitored both downstream and upstream of the chemical injection point. A sodium hydroxide treatment mole ratio of 4 to 1 ($NaOH/H_2S$) will be used initially and the abatement efficiency monitored. The optimum mole ratios will be determined during the hydrogen sulfide abatement operations.

    Upon utilizing the emergency steam release facility, the permittee shall take immediate action to the extent practical to reduce the steam flow and perform the necessary corrective actions. The steam flow rate shall be reduced, as a minimum, to 50 percent of full flow within four (4) hours after initiating the use of the emergency steam release facility.

13. The permittee shall immediately notify the Department of Health of any operational upsets, equipment failure or malfunction which would allow an increase in the emissions of hydrogen sulfide, particulate matter or isopentane. In addition, a written report shall be submitted to the Department of Health within five (5) days of the occurrence. The report shall include a description of the malfunctioning equipment or abnormal operation, the date of the initial failure, the estimated resultant emissions, time and duration of the event, and the methods utilized to restore normal operations. Compliance with this notification provision shall not excuse or otherwise constitute a defense for any violation(s) of this permit, law, rule or order which results from the operational upset, equipment failure or malfunction.

14. The permittee shall maintain a 24-hour telephone service to accept calls concerning this Authority to Construct. This telephone number must be fully operational prior to commencement of construction.

15. Should any of the air quality monitoring stations indicate an ambient hydrogen sulfide, one-hour average concentration greater than 139 micrograms per cubic meter of air, the permittee shall take immediate action to the extent practical to reduce all power plant emissions. Within four (4) hours of the exceedance, the permittee shall terminate all power plant activities not associated with normal power plant operations and contributing to hydrogen sulfide emissions. Following the reduction in project emissions, if the monitoring stations still indicate ambient hydrogen sulfide concentrations in excess of 139 micrograms per cubic meter (one-hour average), the permittee shall curtail the power plant operations, unless the permittee can conclusively show to the Department of Health that the project operations and emissions are not contributing any impact to monitoring site. If the ambient concentration is below 139 micrograms per cubic meter after the project emissions have been reduced, the permittee shall maintain the emissions at this reduced level until such time the Department of Health is assured that the resumption of full activity shall not result in another exceedance of the ambient level of 139 micrograms per cubic meter (one-hour average).

    The permittee shall submit a written report to the Department of Health within two (2) days of the occurrence. The report shall include the date, time and duration of the exceedance, the estimated project emissions and any other emission sources that may have contributed to the exceedance, and all corrective measures and actions taken to reduce project emissions to a minimum. Compliance with this notification provision shall not excuse or otherwise constitute a defense for any violation(s) of this permit, law, rule or order.

16. The operation of the 25 MW geothermal power plant, during periods of operational upsets, equipment failure or malfunctions shall not cause or contribute to an exceedance of the hydrogen sulfide ambient level of 139 micrograms per cubic meter on a one-hour average at or beyond the project boundary.

17. During normal power plant operations, the 25 MW geothermal power plant shall not cause an increase in the ambient hydrogen sulfide concentrations in excess of 5 ppb (one-hour average) above background at or beyond the project boundary.

18. For any hydrogen sulfide concentrations in excess of 5 ppb (one-hour average) above background as indicated by any air quality monitoring station, the permittee has the burden of proving that the 25 MW geothermal power plant did not cause the hydrogen sulfide impact in excess of 5 ppb (one-hour average) or had experienced an operational upset, equipment failure or malfunction.

19. During normal power plant operations, the hydrogen sulfide emissions from the 25 MW geothermal power plant shall not exceed five pounds per hour (three-hour average). During periods of malfunction or regularly scheduled maintenance, best available control technology shall be applied for the hydrogen sulfide emissions.

20. The Department of Health may at any time with reasonable cause, request the permittee to install, operate, and maintain emission monitors to continuously measure and record the hydrogen sulfide and isopentane emissions at any specified location in the power plant.

Planning Commission

25 Aupuni Street, Rm. 109 • Hilo, Hawaii 96720 • (808) 961-8288

Bernard K. Akana
Mayor

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DIV. OF WATER & LAND DEVELOPMENT

CERTIFIED MAIL

October 3, 1989

Maurice A. Richard, Hawaii Regional
Development Manager
Puna Geothermal Venture
101 Aupuni Street, Suite 1014-B
Hilo, HI 96720

Dear Mr. Richard:

Geothermal Resource Permit Application (GRP 87-1)
Puna Geothermal Venture - 25 MW (net) Development
Kapoho, Hawaii TMK: 1-4-01: por. 2, 3, por. 19, & 58

The Planning Commission at its duly held meeting on September 19, 1989, considered this Geothermal Resource Permit Application and based on the following findings, approved the project consisting of 10 integrated back-pressure steam turbine and air-cooled binary cycle turbine power generating modules; up to 30 geothermal wells drilled from 6 well pads; brine and steam pipelines, pollution control equipment; a brine surge tank and holding pond; a switchyard; an office, warehouse, workshop, and control buildings; access roads; and auxiliary facilities such as air compressors, fire protection equipment, etc.:

1. The proposed geothermal development activities would not have unreasonable adverse health, environmental, or socio-economic effects on residents or surrounding property.

The project will occupy approximately 25 acres of surface area within a dedicated 500-acre project area located within the Kapoho Section of the Kilauea Lower East Rift Geothermal Resource Subzone. Approximately 2.75 acres of land will be cleared and leveled for each of 6 drill pads. Each drill site will be engineered to support the drilling equipment and to keep drilling effluent contained onsite and separate from any natural drainage. Each well pad will have drilling mud pits; sumps with gently sloped walls used to temporarily store drilling wastes which typically consist of rock cuttings, waste drilling mud, cement particles, lost-circulation material and other drilling mud additives, and other waste drilling liquids. The high porosity of the volcanic soils and rock in the site area results in rapid downward percolation of rainwater. Concrete pads and berms will be provided to contain possible spills in areas where chemicals are handled. Catch basins, culverts, ditches, and berms will be provided for drainage control.

There are no surface streams or ponds in the vicinity of the proposed drill sites. Ground water will be protected by cementing casing into the hole to depths below sea level.

Based upon biological surveys and monitoring of the Hawaiian Hawk, there are no endangered native species in the project site; however, other wildlife and natural resources will be affected by loss of habitat at the drill site and along any access roads that will be constructed. This habitat loss will be limited to what has been described as scrub vegetation and fallow fields where the primary vegetation is non-native weedy vegetation and abandoned papaya orchards.

Unabated geothermal emissions will be vented to the atmosphere during well cleanout and pipeline clearing. Noise will be generated during well drilling, construction, and operational phases of this project. The sites have been located in agricultural areas away from urban population concentrations. The sites will also be located to take advantage of existing topography and vegetation to muffle or block noise from the drilling operations. The drilling area will be within an area designated as a "hard hat" area. The general public will not be permitted within this area. Average drilling time for each well will be approximately 45 days, with up to five wells drilled at each well pad.

The socio-economic impacts of this activity would not be unreasonable. This project will provide a dependable source of electricity yet decrease dependence on imported petroleum products; provide more employment opportunities; increase personal income and public revenues; and further the informational base to support decisions leading to energy self-sufficiency. This project will support goals stated in the County's General Plan's Energy Element. The economic benefits and security implications of reducing Hawaii's dependence on imported fuels for energy production have been recognized for a long period of time at all levels of government. This has resulted in a general policy of support for alternative energy research and development. The establishment of Geothermal Resource Subzones, where exploration and development are allowable activities, acknowledges the potential higher use of the lands in volcanic rift zones which are generally of marginal value for agriculture and other cultural uses. Indigenous geothermal resources will be developed for the general social and economic well-being of the residents of Hawaii.

2. The proposed geothermal development activities would not unreasonably burden public agencies to provide roads and streets, sewers, water, drainage, school improvements, and police and fire protection.

There should be negligible impact on public infrastructure and services. Personnel associated with the drilling and operations will be small in number. Most of the estimated 23 construction and 19 operations and maintenance jobs at the proposed project will be filled by local employees. Peak construction employment is estimated to be as high as 100. These people will utilize existing facilities and will not require additional services that are not already provided by the County.

Traffic through Pahoa will increase especially during construction. An estimated 35 vehicle round trips per day are expected during wellfield and power plant construction. During normal power plant operations, the traffic generated will fall to about 10 to 18 vehicle round trips per day. These added vehicle trips should not add significantly to the existing traffic levels of 2000 to 3600 vehicles per day at the intersection of the Pahoa to Kalapana Road (Hwy 130) and the Pahoa to Kapoho Road (Hwy 132).

Drilling and power plant operations will require no provisions from public agencies in the form of roads or streets, sewers, drainage, or school enlargement or improvements, and only the normally afforded police and fire protection will be expected. Any necessary access roads will be constructed by the applicant, and water for drilling will be purchased from the Department of Water Supply from their existing distribution system or the applicant will develop its own water supply.

This project will have its own fire protection system and will place minimal demands on the Hawaii County Fire Department. Fire extinguishers are standard equipment on drilling rigs to control fires associated with drilling operations. Water used in drilling can also be used to extinguish any fires that may develop. In addition, drilling muds can be pumped onto any fire that may develop in the vicinity of the rig.

At this time, cesspools are planned as the disposal method of approximately 200 gallons per day of domestic wastewater. This or an alternative disposal method will need to be approved by the the State Department of Health.

3. There are reasonable measures available to mitigate the unreasonable adverse effects or burdens referred to above.

There are mitigation measures to ensure the integrity of the geothermal wells and to prevent blowouts; including the use of blowout prevention equipment that can rapidly choke off the flow of fluids from the well during drilling; the use of conservative safety factors in designing wells and wellhead equipment; the installation of two strings of steel casing cemented in place from the surface into the reservoir caprock; the use of premium grade casing materials and connections to strengthen the wellbore; special cement mixtures with high strength and insulating properties; and regular inspection procedures to test the integrity of the casing and equipment.

Hydrogen sulfide monitors will be operable at the drill site and at off-site locations. The applicant will comply with all federal, state, county, or local rules regarding environmental monitoring.

During drilling and power plant operations, noise levels will be monitored at several sites at and adjacent to the project, and mitigating measures including the relocation of affected individuals will be taken if noise levels exceed acceptable levels.

The drillers will receive safety instructions and instructions on how to contact emergency facilities in the area. Phone numbers for police, fire department, hospital, and other emergency services will be posted in a prominent place at the drill rig, together with phone numbers for the drill supervisor, principal investigator, field manager, and appropriate state and county regulators.

As drilling will be conducted on a 24 hours-a-day, 7 days-a-week basis, the drill site will be lighted during the hours of darkness to permit continuous operations and to provide safe working conditions. The rig will be sited so as to be as unobtrusive as possible and will conform to all Hawaii outdoor lighting regulations. Copies of Hawaii Outdoor Lighting Regulations will be provided to the drilling contractor to insure compliance. After the rig is operational, a lighting survey will be made, and lights adjusted or shielded as necessary to cause the minimum impact.

The power plant site will be more than 2000 feet away from the residents in Lanipuna Gardens and Pohoiki Bay Estates and more than 3400 feet away from the residents in Leilani Estates. There are six residences within a half-mile and another 24 residences within a mile of the power plant site. The relatively close distance between the project and residents prompts the developer to employ the most effective air and noise emission measures.

During normal power plant operation, except for fugitive leaks, geothermal fluids including H2S will not be released to the atmosphere. During outages, steam will be released through rock mufflers after being treated to control the levels of H2S being emitted into the atmosphere. This abatement will keep the H2S concentration below levels known to cause health effects. H2S levels will be monitored to verify the predicted impacts of this project.

Also during normal power plant operation, noise levels will be reduced to meet the Planning Commission's guidelines. Attenuation includes employing engineering measures which range from cooling fan design and building material selection to siting the power plant within the saddle of the the adjacent puu's, orientation of noise emission sources away from receptors, the use landscaping features such as vegetation and berms, etc. In addition noise levels in the community will also be monitored to verify the predicted impacts.

Based on the above, we have concluded that the proposed Geothermal Resource Permit Application has demonstrated that it is consistent with the criteria for issuance of Geothermal Resource Permits as contained in Rule 12-6 of the Planning Commission Rules and Chapter 205-5.1(e), Hawaii Revised Statutes, subject to the following conditions:

1. This Geothermal Resource Permit grants approval for those uses and improvements described in the "Geothermal Resource Permit Application Amendment for the Puna Geothermal Venture Project," dated March 1989, except as amended, modified, or conditioned by this Geothermal Resource Permit. Except as otherwise described in this permit, no other uses are authorized by this permit, and any proposed other uses of the geothermal resource or improvements to the land, whether to be conducted by the permittee or a third-party under contract to, or other agreement with, the permittee, shall be subject to prior review and approval, consistent with the applicable Rules of Practice and Procedure of the Hawaii County Planning Commission. The Planning Director may, upon written request of the permittee, approve deviations from the project layout and uses permitted under this Geothermal Resource Permit if such amendments are consistent with the uses permitted and conditions of this Geothermal Resource Permit. No action pursuant to any such request for deviation by the permittee shall be taken without the written approval of the Planning Director. Amendments to the Geothermal Resource Permit and its conditions may be granted pursuant to Article 12-9 of the Rules of Practice and Procedure of the County of Hawaii Planning Commission.

2. The permittee, its successors, or assigns shall be responsible for complying with all of the stated conditions of approval of this Geothermal Resource Permit. Should the Planning Director determine that there is noncompliance with the Geothermal Resource Permit or its conditions, the permittee may be subject to enforcement of the Geothermal Resource Permit conditions and penalties pursuant to Sections 12-10 and 12-11 of Rule 12 of the Rules of Practice and Procedure of the County of Hawaii Planning Commission.

3. The permittee shall grant unrestricted access to the subject property(ies) to authorized governmental representatives or to consultants or contractors hired by governmental agencies for inspection, enforcement, or

monitoring of activities subject to or authorized by this Geothermal Resource Permit. A designated employee shall be available at all times for purposes of supplying information and responses deemed necessary by the authorized governmental representative in connection with such work.

4. During the period of construction of the project, or during the drilling or testing of any well, the permittee shall submit a weekly written status report to the Planning Department which shall include:

   a. A brief description of the work undertaken during the previous week under the Geothermal Resource Permit;

   b. A description of the work being proposed during the next week under the Geothermal Resource Permit; and

   c. Any other information that the Planning Department may reasonably require which addresses the immediate environmental and regulatory concerns of the County of Hawaii or the requirements of the Geothermal Resource Permit.

5. The permittee shall submit a written semiannual status report to the Planning Department by February 15 (covering the preceding period of July 1 through December 31) and August 15 (covering the preceding period of January 1 through June 30) of each year. The status report shall include, but not be limited to:

   a. A brief summary of the work undertaken during the current reporting period under the Geothermal Resource Permit;

   b. A brief summary of the work being proposed over the next reporting period under the Geothermal Resource Permit;

   c. The results and analysis of all environmental monitoring activities undertaken as required by this Geothermal Resource Permit;

   d. A log of any complaints received by the project and the responses thereto; and

e. Any other information that the Planning Department may reasonably require which addresses the environmental and regulatory concerns of the County of Hawaii or the requirements of the Geothermal Resource Permit.

6. If any environmental monitoring data collected as required under this Geothermal Resource Permit indicates that project operations are creating, or have the immediate potential of creating, excessive health or environmental effects not otherwise permitted by this Geothermal Resource Permit, the permittee shall submit such data to the Planning Department within 48 hours of its identification.

7. The permittee shall maintain a record in a permanent form suitable for inspection and shall make such record available on request to the Planning Director or his designee. The record shall include:

a. Occurrence and duration of any start-up, shut-down, and operation mode of each geothermal well and/or facility;

b. Performance testing, evaluation, calibration checks, and adjustment and maintenance of the continuous monitor(s) that have been installed; and

c. All measurements reported in units compatible with applicable standards/guidelines.

8. Prior to the commencement of any grubbing or grading activity, the permittee shall:

a. Submit a metes and bounds description of all lands to be disturbed including but not limited to all roadways, well pads, steam gathering system corridors, injection system corridors, power plant site, and transmission line corridors to Planning Director;

b. Mark the boundaries of these sites to be disturbed in the field; and

c. Comply with all requirements of Chapter 10 Erosion and Sedimentation Control, Hawaii County Code (the County grading ordinance).

9. No construction or transportation equipment shall be permitted beyond the prescribed boundaries of the areas to be disturbed.

10. Prior to commencing any geothermal well drilling, testing, production, or injection activity approved under this Geothermal Resource Permit, the permittee shall submit to, and secure the approval of, the Planning Director of a hydrologic monitoring program. The program shall, at a minimum, provide for the quarterly monitoring of water levels and appropriate chemical species from existing wells completed within the shallow aquifer in those areas downgradient of the project area, including the Green Lake water supply, as well as from a well located within the project boundary and completed within the shallow aquifer. The monitoring, sampling, and analysis protocols shall be clearly defined in the program submitted to and approved by the Planning Director. The monitoring and sampling shall be conducted by a qualified contractor, and the samples analyzed by a qualified laboratory, selected by the permittee but subject to the approval of the Planning Director. The selected contractor and laboratory shall operate under contract to, and shall be funded by the permittee. The program shall monitor the shallow groundwater immediately prior to, and during, all periods of well drilling, testing, production, and injection activity approved under this Geothermal Resource Permit. The data obtained shall be submitted to the Planning Director in accordance with the requirements contained in this Geothermal Resource Permit for submittal of all collected environmental monitoring data. The County shall make random checks of the ground water supply no less than every two months.

11. If pollution of the shallow ground water is demonstrated to be occurring from the project construction, operation or maintenance activities as determined by the Planning Director in consultation with the Department of Water Supply and the Department of Land and Natural Resources, the permittee shall immediately take those measures necessary to eliminate the source of the pollution meeting with the approval of the affected agencies. If any geothermal production or injection well demonstrates that the integrity of the well casing is lost such that the shallow groundwaters are being, or may immediately be

polluted by the production or injection activity of that well, the permittee shall, as quickly as practical consistent with safety and prudent operating practices, cease the production or injection activity for that well, and the activity not resume for that well until adequate casing integrity is restored to the satisfaction of the Department of Land and Natural Resources.

13. In the event the Department of Water Supply determines that the existing Green Lake county water source becomes contaminated by the permittee's geothermal wellfield system, the permittee shall immediately provide alternative(s) to the water supply, including the hauling of water if necessary as a temporary alternative, which meet the approval of the County's Department of Water Supply and the State Department of Health.

14. Only nonhazardous drilling mud additives, as recognized on the "California Department of Health Services Drilling Mud Additives Used in Nonhazardous Drilling Muds and Fluids" list, shall be used during the drilling of the geothermal wells, and which list shall be on file with the County Planning Department.

15. All drilling mud solids and drill cuttings shall be discharged to and contained within the well pad sump. A disposal site or sites approved by the State Department of Health, prior to any disposal activity covered by this permit, shall be provided for sump contents and other waste materials to be disposed of from the drilling activity. All sumps/ponds shall be purged in a manner meeting with the approval of the State Department of Health. In the event there are no DOH requirements, the applicant and the Planning Department shall request for guidelines from the DOH for the purging of sumps and ponds. Said guidelines shall be available to the community.

16. All geothermal brines, steam condensate, and noncondensible gases produced during normal project operations shall be injected into the geothermal reservoir.

17. Prior to commencing any activity approved under this Geothermal Resource Permit on the project site, the permittee shall submit to, and secure the approval of, the Planning Director of an air quality and meteorological

monitoring program. The program shall include provisions for installation, calibration, maintenance and operation of recording instruments to measure air contaminant concentrations, the specific elements to monitored, the number of stations involved, and frequency of sampling and reporting. The Planning Director shall review and approve the submitted monitoring plan in consultation with and concurrence of the State Department of Health. The monitoring and sampling shall be conducted by a qualified contractor, and the samples analyzed by a qualified laboratory, selected by the permittee but subject to the approval of the Planning Director. The selected contractor and laboratory shall operate under contract to, and shall be funded by the permittee. The program shall monitor the air quality immediately prior to, and during, all periods of well drilling, testing, production, and injection activity approved under this Geothermal Resource Permit. The data obtained shall be submitted to the Planning Director in accordance with the requirements contained in this Geothermal Resource Permit for submittal of all collected environmental monitoring data.

18. The permittee shall apply "Best Available Control Technology" (BACT) for air emissions to all aspects of the project to minimize air quality impacts. BACT means the maximum degree of control for air quality concerns taking into account what is known to be practical and economically viable. BACT for each aspect of the project shall be determined by the Planning Director in consultation with other appropriate governmental agencies involved in the control or regulation of air quality from geothermal development projects. Such determination shall be made prior to issuance of any construction permit for that aspect of the project. BACT shall be subject to review by the Planning Director every five years, commencing with the date of approval of the Geothermal Resource Permit for the wellfield operations, and with the date of full power plant operation for the power plant.

19. The permittee shall control all project emissions of hydrogen sulfide during normal power plant operation so that the increase in the ambient hydrogen sulfide concentration due to these project emissions shall not exceed 5 ppb at or beyond the project boundary.

20. With regard to air emissions, the permittee shall submit to the County Civil Defense and the Planning Department a map and accompanying text that describes predetermined "worst case" impacted areas.

21. Prior to commencing any activity approved under this Geothermal Resource Permit on the project site, the permittee shall submit to, and secure the approval of, the Planning Director of a noise monitoring program designed to adequately ensure project compliance with the noise impact limitations contained in this Geothermal Resource Permit. The program shall include the monitoring of noise immediately prior to and during all periods of activity approved under this Geothermal Resource Permit. The monitoring and sampling shall be conducted by a qualified contractor, and the samples analyzed by a qualified laboratory, selected by the permittee but subject to the approval of the Planning Director. The selected contractor and laboratory shall operate under contract to, and shall be funded by the permittee. This program should also allow the correlation of any complaints of noise from the public with the level of measured noise, the meteorological conditions, and the type of operations which occurred at the site. The data obtained shall be submitted to the Planning Director in accordance with the requirements contained in this Geothermal Resource Permit for submittal of all collected environmental monitoring data.

22. The permittee shall apply "Best Available Control Technology" (BACT) for noise emissions to all aspects of the project to minimize project noise. BACT means the maximum degree of control for noise concerns taking into account what is known to be practical and economically viable. BACT for each aspect of the project shall be determined by the Planning Director in consultation with other appropriate governmental agencies involved in the control or regulation of noise from geothermal development projects. Such determination shall be made prior to issuance of any construction permit for that aspect of the project. BACT shall be subject to review by the Planning Director every five years, commencing with the date of approval of the Geothermal Resource Permit for the wellfield operations, and with the date of full power plant operation for the power plant.

23. The permittee shall notify the Planning Department and any resident within 3500 feet of the permittee's project boundary who has previously requested such notice, at least twenty-four (24) hours in advance of the open venting of each geothermal well and pipeline cleanout and 14 days before commencement of drilling. Initial notification to residents shall be made in writing, offering the opportunity to be placed on the notification list. Any other person may request to be on the list. The permittee shall notify the Planning Department immediately prior to the open venting of any geothermal well and pipeline cleanout. The permittee shall notify the Planning Department following completion of each geothermal well, prior to the demobilization of the drilling rig.

24. Until such time as noise regulations are adopted by the State or County, the permittee shall comply with the following guidelines which shall be enforced by the Planning Department:

a. During power plant and wellfield operations, the permittee shall not exceed a general noise level of 55 dBA during daytime and 45 dBA at night at the current nearest residence. For the purposes of these guidelines, "night" is defined as the hours between 7:00 p.m. and 7:00 a.m.;

b. The allowable noise levels may be exceeded by a maximum of 10 dBA; however, in any event, the generally allowed noise level should not be exceeded more than 10 percent of the time within any 20-minute period, and the permittee shall conduct all operations so as to minimize the occurrence, frequency, and duration of this impact noise;

c. The noise level guidelines specified above shall be waived only for the specified duration of authorized open geothermal well venting from all wells, steam pipeline cleanout periods, and the drilling and testing of wells from well pads E and F. During these authorized periods, BACT shall be applied. In addition, during the drilling and testing of wells from well pads E and F, the permittee shall meet a general noise level of 55 dBA during the day and 50 dBA during the night at the current nearest residence; and

d. For the purposes of these noise conditions, the "nearest residence" is hereby defined as: For three years following the date of granting of the Geothermal Resource Permit, that permanently occupied dwelling nearest the applicable noise emission point as of the date of the granting of this permit; for all following years, that permanently occupied dwelling nearest the applicable noise emission point.

e. Sound level measurements shall be conducted using standard procedures with sound level meters using the "A" weighting and "slow" meter response unless otherwise stated.

25. Pursuant to Article 12-8 of the Rules of Practice and Procedure of the County of Hawaii Planning Commission, prior to initiating construction of the project, the permittee shall submit the following to the Planning Director:

a. Copies of approved permits and other applicable approvals for the project from other county, state, or federal agencies as applicable;

b. Final plans or provisions for monitoring environmental effects of the project as required by this Geothermal Resource Permit or otherwise required to ensure compliance with County rules and the rules of the State Department of Health and Board of Land and Natural Resources and other permit-issuing agencies;

c. A final plan of action to deal with emergency situations which may threaten the health, safety, and welfare of the employees and other persons in the vicinity of the proposed project site; and

d. A final site plan and elevations of proposed temporary and/or permanent structures for the project.

26. Prior to commencing any activity approved under this Geothermal Resource Permit on the project site, the permittee shall submit to, and secure the approval of, the Hawaii County Civil Defense Director a final plan of action to deal with emergency situations which may threaten the

health, safety, and welfare of the employees and other persons in the vicinity of the proposed project site. The plan shall include but not be limited to, the following elements:

a. A description of the project facilities and operations, with site plans identifying areas of potential hazards, such as high pressure piping and the presence, storage and transportation of flammable or hazardous materials, such as lubrication or fuel oil, isopentane, hydrogen sulfide, and sodium hydroxide;

b. A description of emergency services available off-site to respond to any emergency;

c. A description of the current onsite chain of command and responsibilities of project personnel in the event of an emergency; and

d. A description of potential project emergency situations, such as loss of well control, chemical spills, hydrogen sulfide exposure, pipeline rupture, fires, contaminated solids, etc. identifying:

(i) technical data on the nature of the hazard (for example, the concentrations of hydrogen sulfide in the various areas and the hazard associated with these concentrations, the corrosive characteristics of the abatement chemicals), or any data regarding the possible aerial extent of each potential emergency situation;

(ii) the warning systems (such as hydrogen sulfide detectors) used to alert personnel of the hazard;

(iii) the location and use of equipment used to control the hazard (such as fire protection equipment or isolation valves) or repair hazardous equipment (such as welding equipment or casing sleeves), and safety equipment for personnel (such as respiratory packs), including identification of the personnel trained in the use of that equipment; and

(iv) provisions for the monitoring, detection, and inspection of wells and plant facilities for the prevention of emergency situations.

e. Provisions to address natural hazards (such as lava flows, earthquakes, and storms) that identify warning systems, control options, steps for securing and shutting down the facility, personnel evacuation, and notification to appropriate agencies;

f. The location and capabilities of available medical services and facilities and plans for treating and transporting injured persons;

g. Evacuation plans, including meeting points, personnel rosters, and escape routes;

h. Training requirements for personnel, including procedures for emergency shutdown, handling of emergency equipment, spill prevention, first aid and rescue, fire fighting procedures, and evacuation training;

i. Provisions for periodic emergency preparedness drills for personnel;

j. Detailed procedures to be used to facilitate coordination with appropriate federal, state, and county officials during and after any emergency situation; and

k. Procedures to be used to identify and inform all residents within applicable distances of the project of the possible emergency situations, warnings, and responses in advance of commencement of project operations and the methods by which all individuals affected by a given emergency will be notified and evacuated, as necessary.

Copies of the emergency plan shall be made available to the public by the applicant.

27. Reports and records of emergency situations shall be submitted to the Planning Department upon occurrence of such emergencies.

28. Within 48 hours after an earthquake registering 6 or above on the Richter Scale and/or within 48 hours after an eruption has occurred, all wells within 10 kilometers of the epicenter or eruptive center, shall be examined for any physical changes which would alter its downhole integrity. A report of this examination shall be filed with the Planning Department within 48 hours of the examination.

29. In the event the Hawaii County Civil Defense Agency determines that an emergency situation resulted from the permitted geothermal activity, the permittee shall bear all costs of evacuation. The Hawaii County Civil Defense Agency shall be responsible for public and media notification and evacuation of members of the public in the event the Agency deems such action necessary as a result of an emergency situation.

30. Prior to the commencement of any surface disturbing activity, the permittee shall conduct an archaeological survey of those areas planned for surface disturbance not previously surveyed and submit the results of this survey to the Planning Department for review and approval.

31. If construction activities expose any cultural remains, the permittee shall immediately cease work in the area of the cultural remains and contact the Planning Department and the State Historic Preservation Office. As appropriate, a qualified archaeologist shall be retained by the permittee to implement any necessary mitigation measures and monitor further work. Work in the affected area shall not resume until such time that clearance is obtained from the Planning Department.

32. The lighting used shall not interfere with the operations at the observatories located on Mauna Kea. To meet this requirement, the permittee shall comply with the requirements of Chapter 14, Article 9 of the Hawaii County Code, relating to outdoor lighting.

33. All lights shall be at a minimum level consistent with the safety of operations and shall be shielded or directed away from surrounding residential or populated areas and not interfere with important biological resources in the area.

34. The permittee shall submit to, and secure the approval of the Planning Director of a detailed landscaping and siting plan. The siting plan shall show plan and elevational views of all proposed temporary and/or permanent structures for the project. The plan shall also show the site topography, natural features and proposed berms, planting schedules, tree sizes, heights (actual size of trees to be planted), type of irrigation system, etc. Installation of approved landscaping improvements shall be commenced within three weeks from the completion of construction of each well pad, access road, or other facility. The plan shall also include:

a. A landscaping maintenance program;

b. A line-of-sight analysis, being especially sensitive to views from surrounding residences, of the view planes from the site property lines, from the intersection of Leilani Avenue and the Pahoa-Pohoiki Road, for the intersection of the proposed access road and the Pahoa-Kapoho Road, from the intersection of Lauone Street and Hinalo Street in Lanipuna Gardens, and the intersection of the Kapoho-Kalapana Road and the access road to Vacationland; and

c. To the extent possible, the well sites and power plant shall be landscaped and sited to reflect the existing agricultural character of the area, and utilize native plantings.

35. To the extent compatible with engineering and aesthetic considerations, all exterior surfaces shall be rough texture, with no reflective metal, and no reflective glass surfaces oriented toward surrounding residential or populated areas within line of sight. The exterior of all project structures, including fluid conveyance pipelines, shall be painted in colors so as to blend in with the surrounding environment.

36. The permittee shall submit and secure approval of a revegetation/site reclamation plan meeting with the approval of the Planning Director in consultation with the Forestry Division of the Department of Land and Natural Resources. When construction is completed on any individual project site, or if the project area is

abandoned, all denuded areas on and around the project site shall be revegetated in accordance with this plan. Said plan shall include appropriate security to assure its implementation in a timely manner.

37. The permittee shall obtain and maintain those bonds required for project operations by the rules and regulations of the Board of Land and Natural Resources and the Department of Health.

38. The permittee shall obtain and maintain builder's risk and comprehensive liability insurance for project construction and operation activities.

39. The permittee shall notify each resident household within a radius of 3500 feet from any geothermal well at least twenty four (24) hours prior to, and again the morning of, any planned venting of that well. Each resident within this radius of 3500 feet shall be offered the opportunity to voluntarily leave the area during the well venting. The cost of such voluntary leaving, up to a maximum of $100.00 per resident or $200.00 per household, whichever is lesser, shall be borne by the permittee. Upon adequate demonstration to the permittee that any such resident is unable to pursue his normal, legitimate employment or business activity as a result of such voluntary leaving, the permittee shall reimburse that resident for that one day's lost income, in an amount not greater than $150.00.

40. Upon adequate demonstration to the permittee that any adverse alteration of the quality of the water has occurred as a result of venting to the atmosphere, the permittee shall immediately rinse the water catchment system and replace the stored water of any water catchment system within a radius of 3500 feet of any well. Upon adequate demonstration to the permittee that any agricultural crop damage resulted directly from any of the permittee's well venting operations, the permittee shall also provide compensation to the owner of agricultural operations located within a radius of 3500 feet of that well. In either situation, compensation will only be considered if the agricultural crops and water catchment system are inventoried and registered with the permittee prior to the venting. Other requests shall be considered by the permittee on a case-by-case basis.

41. The permittee shall establish and publish a telephone number for use by local individuals for the lodging of complaints or inquiries regarding status of operations. A designated representative of the permittee shall be available, 24 hours a day, to respond to any local complaints or inquiries.

42. Large vehicle deliveries to the project site shall be limited to daylight hours. For the purposes of this condition, daylight hours is defined as the hours between 7:00 a.m and 7:00 p.m. This condition shall not apply for vehicles responding to emergencies.

43. An extension of time for the performance of conditions within the permit may be granted by the Planning Director upon the following circumstances: 1) the non-performance is the result of conditions that could not have been foreseen or are beyond the control of the applicants, successors, or assigns and that are not the result of their fault or negligence; 2) granting of the time extension would not be contrary to the General Plan or Zoning Code; 3) granting of the time extension would not be contrary to the original reasons for the granting of the Geothermal Resource Permit; and 4) the time extension granted shall be for a period not to exceed one (1) year and 5) if the applicant should require an additional extension of time, the Planning Director shall submit the applicant's request to the Planning Commission for appropriate action.

44. All other applicable rules, regulations, and requirements, including those of the State Department of Health and the State Department of Land and Natural Resources shall be complied with.

45. The permittee shall obtain, and comply with the provisions of, permits to drill, modify use or abandon, as appropriate, from the State Board of Lands and Natural Resources for each geothermal well approved under this Geothermal Resource Permit.

46. The permittee shall obtain and comply with the provisions of, Underground Injection Control Permits, as appropriate, from the State Department of Health for all geothermal injection wells approved under this Geothermal Resource Permit. A copy of the UIC Permit and any conditions shall be available in the County Planning Department.

47. The permittee shall obtain, and comply with the provisions of, Authorities to Construct and Permits to Operate from the State Department of Health for all applicable project operations approved under this Geothermal Resource Permit.

48. The permittee shall secure all necessary approvals and clearances including Plan Approval pursuant to Chapter 25 of the Hawaii County Code, within one (1) year from the effective date of the Geothermal Resource Permit.

49. Construction shall commence within one (1) year from the date of receipt of Final Plan Approval.

50. The permittee shall submit a written semiannual status report to the Planning Commission on the permittee's best efforts to address/comply with the "Other Agreements and Recommendations" as contained in Section 5 of the final report on "Mediation of Geothermal Resource Permit Application 87-1" dated August 21, 1989, regarding but not limited to the collateral agreements and commitments the permittee made during the mediation process, and which the permittee considers to be contractual obligations subject to the issuance of a satisfactory Geothermal Resource Permit. The status report shall be submitted by February 15 (covering the preceding period of July 1 through December 31) and August 15 (covering the preceding period of January 1 through June 30) of each year.

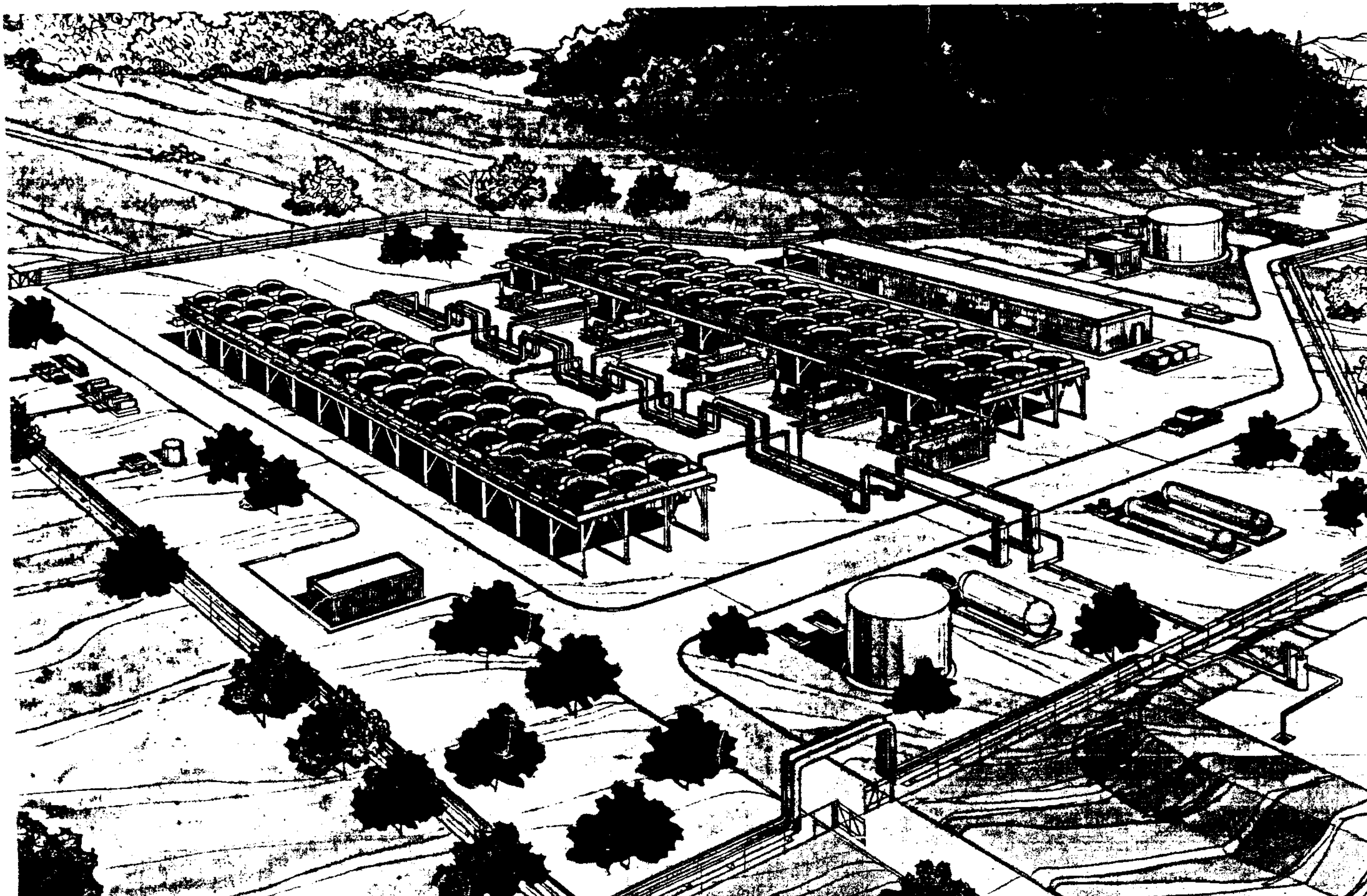
51. Prior to the issuance of the first building/construction permit under this Geothermal Resources Permit (GRP) by the County of Hawaii, the State of Hawaii and the permittee shall each contribute towards a Geothermal Asset Fund or other appropriate existing fund for the purposes of geothermal impact mitigation efforts within the District of Puna. The permittee's initial contribution to the fund shall be a sum of $60,000, due within thirty (30) days after the effective date of this GRP permit, and annual sums of $50,000 due on or before the anniversary date of this GRP permit over a period of eight (8) consecutive years thereafter for a total of $460,000. Annual contributions thereafter shall be determined between the permittee and the State of Hawaii or $50,000 annually, whichever is greater. The State's initial annual contribution to the Geothermal Asset Fund shall be the net revenues derived from the resources generated by the HGP-A well, or a similar amount from other State funding sources

less any allocations entitled to the Office of Hawaiian Affairs and operations and maintenance costs. In the event that future enabling legislation provides for a percentage of the State's geothermal royalties to be allocated to the County, upon concurrence with the County Council, said royalties may also be deposited to the fund. The administration and expenditure of assets from this Geothermal Asset Fund shall be in accordance with rules, regulations and procedures developed for that purpose by the County in accordance with Chapter 91, Hawaii Revised Statutes, and with participation of Puna residents or representatives thereof, which shall include, but not be limited to, provisions and criteria to enable the first priority of distribution for temporary or permanent relocation of those property owners who are found, in accordance with criteria established in the rules, to be adversely impacted by the activities authorized, provided that such relief is applied for within a period of one (1) year of the impact. A priority list of impact mitigation projects may be established by the County Council or agency designated by the Council in conjunction with Puna residents or designated representatives thereof, with the exception of upgrading existing subdivisions in the Puna District to current subdivision standards and specifications of the County of Hawaii. Should any other district(s) of the County of Hawaii be proved to be negatively impacted by activities authorized under this or any other subsequent GRP, that district shall receive a pro rata share of the fund assets as may be determined by the County Council or agency designated by the Council with expenditures to follow a prioritized schedule determined as outlined above. The rights granted to the permittee shall not be conditioned upon any contribution or further participation by the State in the fund nor with respect to the creation, management, and operation of the fund other than set forth above.

Sincerely,

Gary Mizuno, Chairman
Planning Commission

cc: Mr. Peter Adler
Mediation Parties (list)
DBED
DOA
DLNR/Honolulu
DOH
Mr. Ralph Matsuda



JOHN WAIHEE
GOVERNOR OF HAWAII

STATE OF HAWAII
DEPARTMENT OF LAND AND NATURAL RESOURCES
P. O. BOX 621
HONOLULU, HAWAII 96809

WILLIAM W. PATY, CHAIRPERSON
BOARD OF LAND AND NATURAL RESOURCES

LIBERT K. LANDGRAF
DEPUTY

AQUACULTURE DEVELOPMENT PROGRAM
AQUATIC RESOURCES
CONSERVATION AND ENVIRONMENTAL AFFAIRS
CONSERVATION AND RESOURCES ENFORCEMENT
CONVEYANCES
FORESTRY AND WILDLIFE
LAND MANAGEMENT
STATE PARKS
WATER AND LAND DEVELOPMENT

JUN 5 1989

Mr. Duane Kanuha
Director
Planning Department
County of Hawaii
25 Aupuni Street
Hilo, Hawaii 96720

Dear Mr. Kanuha:

Thank you for the opportunity to review and comment on the application for a Geothermal Resource Permit submitted by Puna Geothermal Venture (PGV).

We have no major objections regarding the 25 MW geothermal project proposed for the island of Hawaii, but would like to offer the following comments:

1) The PGV application states that up to a maximum of 500 gallons per minute (720,000 gal/day) of water may be required for re-injection operations to maintain injection flow and to provide a sufficient quantity of fluid to absorb the noncondensable gases. It is indicated that this supplemental water may be supplied by one or two wells developed near the plant site.

   The applicant (PGV) should be advised that pursuant to the Department of Land and Natural Resources' Administrative Rules, Chapter 13-168, a well construction and pump installation permit, in addition to a well completion report will be required for the construction of any proposed water well. Futhermore, the applicant shall be required to comply with all other applicable regulations identified within that chapter.

2) Pursuant to PGV's proposal to re-inject geothermal fluids and noncondensable gases back into the geothermal reservoir, and in response to community concerns regarding potential impacts to the ground water aquifer down gradient from the site, it is recommended that if water wells are to be developed, that they be strategically sited within the project area so that they may serve as monitor wells as well as sources of supplemental water.

   Placement of these supply wells down gradient from the injection well sites will allow for periodic sampling of the existing ground water aquifer and the monitoring of the proposed injection operations.

3) It is futher recommended that the applicant file monthly reports of re-injection data, including but not limited to, quantity of fluids injected, chemical composition, and any changes in injection pressures which may indicate that the injected fluid is no longer confined to the intended zone of injection.

4) All work shall be performed in accordance with the Department of Land and Natural Resources' Administrative Rules (Chapters 13-183 and 13-184), and all other applicable Federal, State, and County laws, ordinances, rules and regulations pertaining to the lands and permittee's operations including, but not limited to, all water and air pollution control laws, and those relating to the environment.

5) If any unanticipated sites or remains of historic or prehistoric interest (such as shell, bone, or charcoal deposits, human burials, rock or coral alignments, paving, or walls) are encountered during the applicants operation, the applicant shall stop work and contact the State Historic Preservation Office at 548-7460 or 548-6408 immediately.

Thank you again for the opportunity to comment on the subject application and should you have any questions, please contact Dan Lum at 548-7643.

Very truly yours,

for William Paty

WILLIAM W. PATY

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c- Sono

ORMAT®

May 22, 1989
Reference No. 891415

Mr. William Paty
Chairman
Board of Land and Natural Resources
Kalanimoku Building, #130
1151 Punchbowl Street
Honolulu, Hawaii 96813

Subject: Well Modification Permit Request

Reference: Geothermal Well: Kapoho State #1-A
Geothermal Resources Mining Lease R-2
Location TMK 1-4-01:02 Kapoho, Puna District, Hawaii County Leased to Kapoho Land Partnership

Dear Mr. Chairman:

A Department of Land and Natural Resources (DLNR) permit exists for the drilling and completion of the reference well. Since the conclusion of drilling and flow testing in 1985, Kapoho State #1-A has been maintained in a shut-in status with periodical gas cap ventings and incineration or burning of the exhausted gases. Puna Geothermal Venture (PGV) has closely monitored this well and complied with DLNR reporting requirements.

Puna Geothermal Venture herewith submits a Well Modification Permit request consistent with Chapter 183 of Title 13, Subchapter 183-65-4.

The attached work description and well casing configuration drawing including the approximate location of the proposed cement plug is attached for reference.

In brief, the PGV request is based on a technical need to periodically service the wellhead assembly to maintain a high standard of reliability and integrity. This routine servicing process is also timed to fit within the overall 30 MW development schedule and expected County permitting approvals and related requirements now in progress.

PUNA GEOTHERMAL VENTURE

☐ 101 Aupuni Street Suite 1014-B, Hilo, Hawaii 96720 • Telephone (808) 961-2184 • Facsimile (808) 961-3531
☐ 610 East Glendale Ave., Sparks, Nevada 89431-5811 • Telephone (702) 356-9111 • Facsimile (702) 356-9125

Your early consideration and approval will be appreciated. Please contact the Hilo office of Puna Geothermal Venture if you or your staff have any questions about the above request.

Sincerely,

Maurice A. Richard
Hawaii Region
Development Manager

Attachment

MAR/ci

11 May 1989

Program to Temporarily Suspend KS-1A with Cement Plug

1) Purpose of Work

It will be at least a minimum of a year before KS-1A is needed for production service. Therefore PGV has decided to temporarily suspend the well by setting a 150 foot cement plug in the casing at 3000 feet. This will eliminate the need for further gas burns and will permit the wellhead to be serviced and the condition of the production casing to be checked in preparation for putting the well in service.

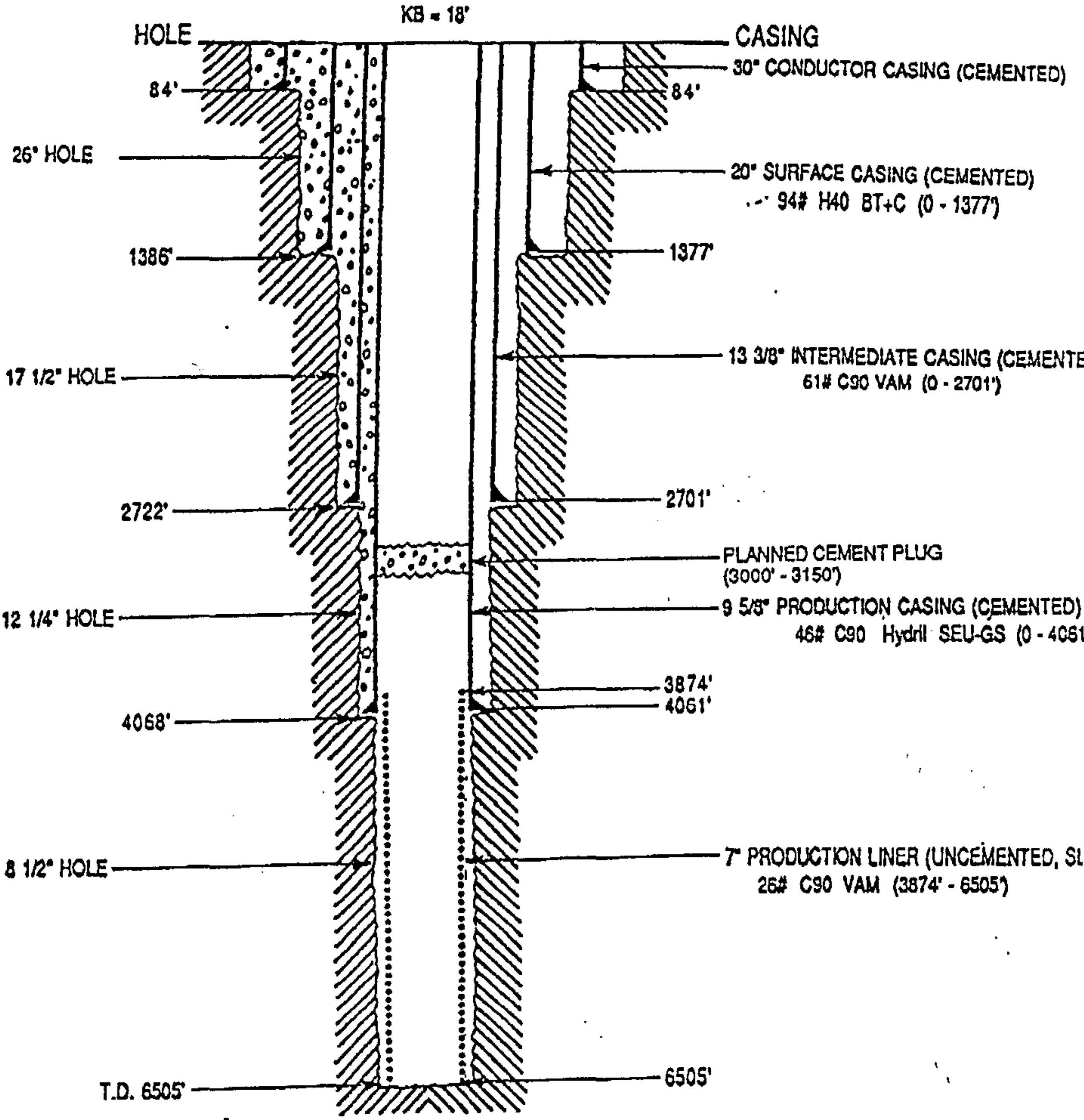
2) Plan of Work

The design of KS-1A showing the planned cement plug is shown in the attached figure. The setting depth of 3000 feet was chosen in order that the reservoir pressure beneath the plug will be balanced by the pressure exerted by the column of water in the wellbore above the plug. A rig will not be needed to carry out the work.
The operation is planned as follows :

1. Run sinker bar to 4500 feet.
2. Run a static pressure and temperature survey to 4500 feet.
3. Nipple-up pump to 3" side valve and kill well by slowly pumping cold water.
4. With the well killed run an 8" gauge ring to 3500 feet. Continue to pump water to maintain kill.
5. Run temperature survey to 4000 feet while maintaining kill to assess wellbore temperatures for cement slurry design.
6. Insert 9 5/8" bottom wiper plug through wellhead.
7. Pump 75 gallons (25 liner feet) water on top of plug.
8. Mix 60 cu ft (150 liner feet) geothermal cement and drop on top of water.
9. Insert top wiper plug and displace cement plug to 3000 feet with water (220 barrels).
10. Wait on cement 24 hours.
11. Run sinker bar to top of cement to check depth.
12. Shut-in wellhead and secure.

The operation is anticipated to take a total of 5 to 7 days.

KAPOHO STATE #1A WELL



Planned Cement Plug in KS-1A

RECEIVED

ORMAT®

March 28, 1989
Reference No. 89071

89 MAR 29 A 9:03

Mr. Duane Kanuha
Director
Planning Department
County of Hawaii
25 Aupuni Street
Hilo, Hawaii 96720

DIV. OF WATER & LAND DEVELOPMENT

Re: Puna Geothermal Venture Project Geothermal Resource Permit Application Amendment - Additional Information

Dear Mr. Kanuha:

As indicated in our February 10, 1989 letter, Puna Geothermal Venture (PGV) hereby submits additional information to supplement the Puna Geothermal Venture Project Geothermal Resource Permit (GRP) Application Amendment on December 30, 1988. To facilitate the review of this additional information by your staff, and to enable a clearer understanding of the project by the general public, PGV has incorporated this additional information into the text of the original application amendment. Accordingly, the attached twenty-five (25) copies of the additional information are presented in the form of a complete GRP Application Amendment, and are intended to replace, in their entirety, those copies of the GRP application amendment submitted in December 1988, which should now be discarded. Also attached are five (5) full size copies of the oversize blueline drawings which are also reproduced in an 11" x 17" format in the application amendment.

This additional information provides a more thorough description of the proposed 25 MW (net) PGV Project and its environmental impacts. The additional information falls into three broad categories:

1) Additional descriptions of the environment in the project area, taken principally from previous studies at Puna;

2) Additional details regarding aspects of the proposed project based, in part, on further progress on the design for the project; and

3) Additional refinements in the analyses of the potential impacts of the proposed project, which have been developed both for this permit and the Authority to Construct Permit applications for the PGV Project power plant and wellfield, submitted concurrently to the State Department of Health.

PUNA GEOTHERMAL VENTURE

☐ 101 Aupuni Street Suite 1014-B, Hilo, Hawaii 96720 • Telephone (808) 961-2184 • Facsimile (808) 961-3531
☐ 610 East Glendale Ave., Sparks, Nevada 89431-5811 • Telephone (702) 356-9111 • Facsimile (702) 356-9125

A large body of environmental information about the proposed project area has previously been developed, including the data presented in the Geothermal Resource Permit application originally submitted by PGV on December 10, 1986 and data presented in the Puna Geothermal Venture Project Final Environmental Impact Statement, accepted by the Planning Department December 28, 1987. The GRP application amendment submitted in December, 1988 originally only referenced this information; now the applicable data has been incorporated into the attached document.

The additional details regarding aspects of the proposed project includes both more information on subjects included in the December, 1988 GRP application amendment and refinements in the project design made as a result of recent engineering analyses. Much of the new information is explanatory, e.g., the document clarifies that the GRP is for a 500-acre project area, but the proposed project will occupy only about 5 percent of the surface of this area (25 acres). More detail has been included on the proposed drill rig layout and operation, and new figures have been added to the description of the wellfield facilities (Section 3.2.1) to clarify the nature of proposed drilling activities. A new section (Wellfield Development Plan, Section 3.2.1.1) has been included to discuss the number of wells and the order in which PGV anticipates drilling these wells, although the document also indicates that this sequence may change as more reservoir data is obtained. To help visualize the proposed power plant, photographs of Ormat Energy Converter (OEC) units and air-coolers, installed in Nevada and California geothermal power plants, have been included in Appendix C. An artist's rendering of the project is also being prepared, which will be submitted shortly.

The refinements in project design since the December, 1988 GRP application amendment mostly affect the internal layout of the power plant site. These refinements are summarized as follows:

1. The 25 MW (net) project will now consist of ten (10) modules. Each module will contain a 1.8 MW back-pressure steam turbine that exhausts into a 1.2 MW OEC unit, each connected to a common nominal 3 MW generator. Each OEC unit will generate power from the low-pressue exhaust steam of a steam turbine, and the working fluid in the OEC unit binary cycle (isopentane) will be condensed by air coolers. In this design, the geothermal fluids never come in contact with the atmosphere during normal operation and the plant has a lower profile (maximum 24 feet for principal components).

2. The configuration of the air coolers has been changed, and several of the auxiliary facility locations have been moved, which alters the layout but not the size or boundary of the power plant site. The site plan and elevation drawings have been revised, and oversize drawings have been included to show the location of equipment and the process flows in detail.

3. The emergency steam release facilities (rock mufflers and holding pond) have been moved to approximately 250 feet southeast of the power plant site to improve dispersion of emergency steam releases, which will occur less than one (1) percent of the time.

4. The isopentane emergency release system has been revised to vent through ten individual stacks, which rise eight (8) feet above the air coolers, to enhance the dispersion of any isopentane emissions.

5. The temporary construction yard has been moved slightly, and a more detailed description of this and other temporary facilities is included.

6. The duration of infrequent project emissions have been more clearly defined: unabated emissions during drilling with aerated water or mud will be less than ten (10) minutes per event; unabated emissions during well venting will be less than four (4) hours per well; pipeline cleanout will last for thirty (30) minutes per pipeline; H_2S emissions from emergency steam releases will be reduced by 98 percent; and emergency isopentane releases will be less than a few minutes a year.

The most recent analyses of the air quality impact of the proposed project shows that more than 99 percent of the time, project emissions will be limited to fugitives, with negligible impacts. The greatest impacts from hydrogen sulfide will come from well venting, although these impacts will be limited to less than about one-half the proposed state hydrogen sulfide ambient air quality standard by scheduling venting to periods when winds are equal or greater than 4 m/s.

The noise impact analysis shows that the noise level from the power plant can be controlled to meet the county geothermal guidelines for residential areas during nighttime. Mitigation measures are proposed to reduce the impacts from well drilling.

Finally, we should point out that the proposed PGV Project has not direct relationship to the scientific observation hole (SOH) program now being proposed by the University of Hawaii, although one SOH location is within the PGV Project area and will provide useful information on the reservoir. The PGV Project can and will proceed independently of the SOH program. In addition, the proposed PGV Project has no direct relationship to the HGP-A Project, located immediately adjacent to the proposed PGV Project. The design and operation of the PGV Project is completely different than that of the HGP-A Project, and these fundamental differences, principally the injection back into the geothermal reservoir of all geothermal fluids and gases without use of brine ponds during normal operations, will result in a project which will have none of the major impacts associated with the HGP-A project, such as the continuous emission of H_2S or the silica deposits which occur with the brine ponds.

PGV would like to thank you and your staff for your assistance to date with this application amendment, and offer our complete cooperation in your timely review and early approval of this PGV Project Geothermal Resource Application Permit.

Sincerely,

Maurice A. Richard
Puna Geothermal Venture
Hawaii Regional Development
Manager

Attachments

cc:
D. Carey w/attachments

MAR/ci

State of Hawaii
DEPARTMENT OF LAND AND NATURAL RESOURCES
Division of Water and Land Development
Honolulu, Hawaii

March 10, 1989

Chairperson and Members
Board of Land and Natural Resources
State of Hawaii
Honolulu, Hawaii

Gentlemen:

Approval of Amendment to
Plan of Operations for 25 MW Geothermal Project,
State Mining Lease No. R-2, Kapoho, Puna, Hawaii

As required by State Mining Lease No. R-2 and Administrative Rules 13-183, Puna Geothermal Venture, sublessee, has submitted for Board approval an amendment to Plan of Operations for a geothermal project involving a 25 Megawatt power plant and associated well field.

The amended 25 MW project will be located in the Kapoho section of the Kilauea Lower East Rift Geothermal Resource Subzone in Puna, Hawaii, and will sell geothermal produced electricity to Hawaii Electric Light Co. for use on the Island of Hawaii. The amendments to the original Plan of Operations (December 1986) will reduce potential environmental impacts through the use of back-pressure steam turbines, air-cooled binary cycle steam turbines, and the injection of spent geothermal fluids and gases back into the geothermal reservoir at depth.

The completion date of the first phase which will produce 12.5 MW of electricity is expected to be late 1989. The second phase which will produce an additional 12.5 MW is expected to be completed by mid 1990.

RECOMMENDATION:

That the Board approve the amendment to Plan of Operations submitted by Puna Geothermal Venture for a 25 MW geothermal project on State Mining Lease No. R-2, subject to the following conditions:

(1) That Puna Geothermal Venture comply with all applicable statutes, ordinances, rules and regulations of the Federal, State, and County governments.

(2) Other terms and conditions as may be prescribed by the Chairperson.

Respectfully submitted,

MANABU TAGOMORI
Manager-Chief Engineer

APPROVED FOR SUBMITTAL

fr WILLIAM W. PATY, Chairperson

Approved by the Board of
Land & Natural Resources

RECEIVED

89 FEB 27 P 3:20

DIV. OF WATER & LAND DEVELOPMENT

STATE OF HAWAII
DEPARTMENT OF LAND AND NATURAL RESOURCES
Office of Conservation and Environmental Affairs
Honolulu, Hawaii

FEB 27 1989

FILE NO.: 89-383
DOC. NO.: 5210E

MEMORANDUM

TO: Mr. Manabu Tagomori, Deputy Director
Commission on Water Resource Management

FROM: Roger C. Evans, Administrator
Office of Conservation and Environmental Affairs

SUBJECT: Review of Puna Geothermal Venture's (PGV) Amendment to Plan of Operation for the 25 MW Geothermal Project

According to Mr. Maurice Richard's correspondence, principal among the proposed changes is the use of back-pressure steam turbines, in combination with air-cooled binary cycle turbines, in place of the steam turbines and cooling towers proposed by Thermal Power Company (TPC).

A benefit from the amendment is that it will essentially eliminate hydrogen sulfide emissions, while most other environmental impacts from this project will be the same as those described in the Puna Geothermal Venture (PGV) Project Final EIS. The Amor Corporation's proposed PGV Project will be located on the same site as the PGV project proposed by TPC, and will use the same well pad locations and the same geothermal resource.

As such, OCEA has no concerns about the amendment that would impact our programs, and regard the elimination of the hydrogen sulfide emissions as a benefit to the 25 MW Geothermal Project.

Please feel free to call me or Roy Schaefer of our Office, at 7837, if you have any questions.

ROGER C. EVANS

CHANGES TO THE PUNA GEOTHERMAL VENTURE PROJECT GEOTHERMAL RESOURCE PERMIT APPLICATION (VERSION OF DECEMBER 1988)

<u>Changes Made in Response To Questions Asked by the County of Hawaii:</u>

1) Believing that reviewers of the Geothermal Resource Permit Application (GRP) would be confused by the many references to information presented in the Environmental Impact Statement (EIS) prepared for the previous Puna Geothermal Venture (PGV) Project, the County asked that the GRP be revised to incorporate into the GRP all the pertinent information from the EIS which is required by Rule 12. In response, PGV is revising the GRP to include some additional information from the EIS regarding geology, air quality, noise, and visual impacts, among others, and reviewing all references to the EIS in the GRP to make certain that the EIS is only presented as a source of information, not a document which must be reviewed to understand the PGV GRP.

2) At the request of the County, PGV is revising the GRP to include additional specific information regarding the drill rig layout and operation, and the potential impacts and mitigation measures for noise and visual aspects of the geothermal well drilling operation.

3) To assist the County, PGV has rewritten the section which describes the 816 acres geothermal lease, the 500 acres for which this GRP is applied, and the 25 acres of actual surface disturbance.

4) The County has asked for additional discussion of the activities described on the project development schedule. Specifically, with regard to the power plant development, Ormat has indicated that the power plant will consist of 10 modular units, each consisting of an approximately 1.8 MW back pressure steam turbine and a 1.2 MW OEC modular binary turbine unit, connected to a common 3 MW generator unit. PGV has also indicated that with regards to the three start-up situations identified in Figure 3-14 of the GRP: 1) the initial stage will consist of operating only some of the OEC units without the steam turbines; 2) the middle stage will consist of operating 5 steam turbine/OEC unit modules and 5 OEC-only modules; and 3) completion will be reached when all 10 steam turbine/OEC modules are operational. Depending on the final power sales agreement with HELCO, there is also a possibility that the first two stages will be combined into one stage of approximately 12.5 MW, consisting of the 10 OEC units only.

5) In response to the County's request for additional information regarding the wellfield development plan,

including the order in which the wells would be drilled and their bottomhole locations, PGV has created a new section of the GRP for describing the current wellfield development plan and its rationale, and providing a proposed initial sequence for well drilling. Although not proposing specific bottomhole locations for the geothermal wells, PGV is revising the GRP to include additional information regarding why the wells will be directionally drilled and how the decisions will be made regarding the order in which the wells will be drilled and the bottomhole targets selected.

6) The County has asked about how the proposed PGV Project relates to other activities proposed for this same project site area, including the scientific observation holes. PGV has indicated that there is no direct relationship between those proposed scientific observation holes and the proposed PGV Project, although some of the information produced by the scientific observation hole program may be useful to the PGV Project, and PGV may desire similar information on its leases in the future.

7) The County has asked PGV to provide more and better information to help them visualize what the project will look like. To the extent that this project will be similar to other geothermal projects in Nevada and California, PGV has attached to the revised GRP several photographs and with explanatory material regarding geothermal power plants which utilize OEC units and/or air cooling. In addition, the building schematics have been altered and improved, and additional information regarding the aesthetic impact of the project (elevations for temporary structures and the geothermal drilling rig) has been included. Additional information is also provided regarding the potential visual impacts and mitigation measures of the project and an artist's rendering is being prepared which will be submitted at a later date.

8) In response to a concern that the proposed brine holding pond will end up looking like the geothermal brine ponds utilized by the HGP-A Project, PGV has revised the GRP to indicate that the PGV holding pond would be utilized only under certain emergency situations (less than one percent of the time), rather than the continuous use that the HGP-A makes of its pond; that the holding pond may receive condensate in addition to the geothermal brine; and the brine would be flashed in the rock muffler prior to dishcarge to the pond.

9) To clarify the question of how much isopentane may be releaced via the emergency vent, the GRP has been revised to indicate that the maximum credible release of isopentane under any emergency situation would be less than 2,500 lbs, and that emission of this much isopentane would probably only occur in a series of small emissions over a short period of time through the relief valve.

10) Finally, in response to a County question regarding comparisons with the PGV Project and the HGP-A Project, we have included some additional information comparing the two projects.

<u>Changes Made in the Project Design as a Result of Ongoing Project Design Efforts:</u>

1) The size of the air cooler units has been altered to make them wider (from 40 feet to 66 feet), which has resulted in a substantial decrease in the length of the two batteries of air coolers (from 455 feet to 281 feet).

2) As a result of optimization studies, and to increase reliability and flexibility in operation and maintenance, the power generation equipment has been designed to include ten back-pressure steam turbine/OEC modules connected to a common 3 MW generator, to be laid out in two 5-module banks. As a result, the steam turbine building has been removed from the plot plan, which results in a smaller, lower-profile building for the control room and workshops.

3) As a result of additional investigations regarding the reliability of the hydrogen sulfide abatement equipment, the absorber has been deleted from the project equipment as being an unnecessary back-up to the in-line mixer.

4) The temporary construction yard has been expanded to both sides of the principle access road to provide security during construction, and additional information regarding the structures and facilities to occupy this has been provided.

5) The rock mufflers (part of the emergency steam release system) have been moved outside of the power plant battery limit approximately 350 feet south of the southeast corner of the power plant site, to ensure that during almost all wind conditions the rock mufflers will be downwind of the

power plant site and to improve dispersion. In addition, the holding pond has been relocated from the west side of the power plant site to outside of the southeast corner of the power plant site, to be adjacent to the rock mufflers and downwind of the power plant.

6) The isopentane emergency release venting system has been revised to vent through ten low-profile, individual stacks, one each for each OEC unit, venting above the air coolers for better dispersion.

7) Within the battery limits of the power plant site, substantial rearrangement of power plant structures and facilities have occurred.

PLANNING DEPARTMENT

COUNTY OF HAWAII

25 AUPUNI STREET • HILO, HAWAII 96720
(808) 961-8288

BERNARD K. AKANA
Mayor

DUANE KANUHA
Acting Director

WILLIAM L. MOORE
Acting Deputy Director

January 25, 1989

Mr. Maurice A. Richard
Regional Development Manager
Puna Geothermal Venture
101 Aupuni St., Suite 1014B
Hilo, HI 96720

Dear Mr. Richard:

Geothermal Resource Permit Application
Puna Geothermal Venture's 25MW Power Plant

We have received your letter of December 30, 1988, transmitting your "Amendment To The Geothermal Resources Permit Application for the Puna Geothermal Venture Project." My staff is continuing to review this submittal and we will respond to you under separate cover whether this submital does/does not constitute a properly filed application. The format used to present your information is particularly cumbersome in its numerous references to the previously submitted EIS. Please note that this EIS has not been widely circulated and will not be readily available for reference by other reviewers.

Meanwhile please bear with us. We expect to complete our detailed comments shortly.

Sincerely,

DUANE KANUHA
Acting Planning Director

RKN:aeb

JOHN WAIHEE
GOVERNOR OF HAWAII

WILLIAM W. PATY, CHAIRPERSON
BOARD OF LAND AND NATURAL RESOURCES

DEPUTIES

LIBERT K. LANDGRAF
MANABU TAGOMORI
RUSSELL N. FUKUMOTO

AQUACULTURE DEVELOPMENT PROGRAM
AQUATIC RESOURCES
CONSERVATION AND ENVIRONMENTAL AFFAIRS
CONSERVATION AND RESOURCES ENFORCEMENT
CONVEYANCES
FORESTRY AND WILDLIFE
LAND MANAGEMENT
STATE PARKS
WATER AND LAND DEVELOPMENT

STATE OF HAWAII
DEPARTMENT OF LAND AND NATURAL RESOURCES
P. O. BOX 621
HONOLULU, HAWAII 96809

FEB 22 1989

Mr. Maurice A. Richard
Hawaii Regional Development Manager
101 Aupuni Street, Suite 1014-B
Hilo, Hawaii 96720

Dear Mr. ~~Richard~~: Maurice

The Department of Land and Natural Resources acknowledges the acceptance of your Amendment to the Plan of Operations for State Geothermal Resource Mining Lease No. R-2.

The amendment to the previously submitted Plan of Operations is under review by our Department and will be processed in a timely manner. Notification of the date and time at which the matter will be brought before the Board of Land and Natural Resources will be forthcoming.

Should you have any questions, please contact Manabu Tagomori at 548-7533.

Very truly yours,

Bill

WILLIAM W. PATY

JOHN WAIHEE
GOVERNOR OF HAWAII

WILLIAM W. PATY, CHAIRPERSON
BOARD OF LAND AND NATURAL RESOURCES

LIBERT K. LANDGRAF
DEPUTY

STATE OF HAWAII

DEPARTMENT OF LAND AND NATURAL RESOURCES
P. O. BOX 621
HONOLULU, HAWAII 96809

AQUACULTURE DEVELOPMENT PROGRAM
AQUATIC RESOURCES
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CONSERVATION AND RESOURCES ENFORCEMENT
CONVEYANCES
FORESTRY AND WILDLIFE
LAND MANAGEMENT
STATE PARKS
WATER AND LAND DEVELOPMENT

January 25, 1989

MEMORANDUM

TO: Manabu Tagomori, Deputy Director, Commission on Water Resource Management

FROM: Ralston H. Nagata, State Parks Administrator

SUBJECT: Puna Geothermal Venture's Amendment to Plan of Operation for 25 MW Geothermal Project
Kapoho, Puna, Hawaii
TMK: 1-4-1: 1, 2, 19

HISTORIC SITES SECTION CONCERNS:

The documentation indicates the same project area will be used as previously planned. Our April 28, 1987 conclusion of "no effect" to significant historic sites still applies. The cultural resources section adequately covers historic preservation concerns with physical historic properties and it also addresses the recent concerns regarding Pele and worshipping rights, which is a concern separate from the historic preservation laws under our jurisdiction (pp. 115-117).

RALSTON H. NAGATA

January 19, 1989

MEMORANDUM

TO: State Parks, Forestry & Wildlife, Aquatic Resources, Aquaculture Development Program, and Office of Conservation and Environmental Affairs

FROM: Manabu Tagomori, Deputy Director
Commission on Water Resource Management

SUBJECT: Review of Puna Geothermal Venture's (PGV) Amendment to Plan of Operation for the 25 MW Geothermal Project

Puna Geothermal Venture (PGV) has submitted an amendment to the previously submitted Plan of Operation (POP) for a 25 MW geothermal power plant and associated well field. The attached document entitled "Geothermal Resource Permit Application Amendment for the Puna Geothermal Venture Project" supercedes the earlier POP which was submitted to DLNR and routed to your division for review and comment.

The amendment contains details of PGV's plans for incremental wellfield development and construction of a power plant facility. The PGV project is proposed for the area covered under DLNR Geothermal Resource Mining Lease R-2, located within the Kapoho Section of the Kilauea Lower East Rift Geothermal Resource Subzone.

We would appreciate your review of this document as it pertains to your area of concern and the return of the document with your comments to our division by Monday, January 30, 1989. To facilitate your review of the POP, we would like to invite your designated representative to attend a presentation of the project by the developer (ORMAT Energy Systems, Inc.) on Thursday, January 26, 1989, at 10:00 am in the DOWALD conference room.

Your continued assistance and cooperation is greatly appreciated. Should you have any questions, please contact Dan Lum at Ext. 7643.

Manabu Tagomori
Deputy Director

Attach.

XEROX TELECOPIER 295 ; 1-18-89; 8:47 PM; 5361398 → 5486461 ; # 1

1-18-89 WED 20 :?9 THERMAL POWER P.01

FACSIMIL ESSAGE from PUNA GE(ERMAL VENTURE

276

WL

101 Aupuni Street Suite 1014-B, Hilo, Hawaii 96720
Phone: (808) 961-2184 Telefax: (808) 961-3531

MSG NO. 9021 **DATE:** January 18, 1989 **PAGE #**1 **of** 7

To: Department of Land and Natural Resources **Fm:** Maurice Richard

Attn: William W. Paty **CC:** M. Tagomori, D. Lum / DLNR

RE: 89011/Geothermal Mining Lease R-2 - Amendment to Plan of Operation
89012/Geothermal Mining Lease R-1, R-2, R-4 - Designation of Operator and Designation of Agent

Attachments for letter addressed to William W. Paty, reference number 89011 sent under separate cover.

Please provide Mr. Tagomori and Mr. Lum with copies of these letters with the necessary attachments, as necessary.

Thank you.

WL

276

ORMAT®

January 18, 1989
Reference No. 89012

RECEIVED
89 JAN 19 A7:49
DEPT. OF LAND & NATURAL RESOURCES
STATE OF HAWAII

Mr. William W. Paty, Chairperson
Board of Land and Natural Resources
Kalanimoku Building
1151 Punchbowl Street
Honolulu, Hawaii 96813

Re: Geothermal Mining Lease R-1, R-2, and R-4 - De[illegible] ator and Designation of Agent

Dear Chairman Paty:

Puna Geothermal Venture (PGV), as sublessee of Geother[illegible] Leases R-1, R-2, and R-4, and pursuant to Department of Land [illegible] Natural Resources (DLNR) Administrative Rules, Title 13, Chap[illegible], Section 45(f), hereby designates AMOR VIII Corporation as op[illegible] and all of the above-named leases. AMOR VIII Corporation, [illegible] of the two partners forming PGV, has previously filed, pur[illegible] letter of October 24, 1988 to your office, a blanket well indemnity bond as required under DLNR administrative rules Section 13-183-68.

Pursuant to Section 13-183-64 of the DLNR administrative regulations, PGV and AMOR VIII Corporation also hereby designate Mr. Maurice A. Richard as their agent upon who may be served all orders, notices, and processes of the DLNR at the following address:

Mr. Maurice A. Richard
Hawaii Regional Development Manager
101 Aupuni Street, Suite 1014-B
Hilo, Hawaii 96720
Telephone (808) 961-2184
Facsimile (808) 961-3531

January 18, 1989
Reference No. 89012
Page 2

Please do not hesitate to contact me if you have questions concerning the above information or require any additional information to complete the requested actions.

Sincerely,

PUNA GEOTHERMAL VENTURE

By: AMOR VIII CORPORATION
General Partner

By: Maurice A. Richard
Authorized Representative

cc:
M. Tagomori - DLNR
D. Lum - DLNR

MAR/ci

January 18, 1989
Reference No. 89011

ORMAT®

Mr. William W. Paty, Chairperson
Board of Land and Natural Resources
Kalanimoku Building
1151 Punchbowl Street
Honolulu, Hawaii 96813

Re: Geothermal Mining Lease R-2 - Amendment to Plan of Operation for the 25 MW Puna Geothermal Venture Project

Dear Chairman Paty:

AMOR VIII Corporation (AMOR VIII), as designated operator for Geothermal Mining Lease R-2, hereby requests that the Board of Land and Natural Resources (BLNR), pursuant to Department of Land and Natural Resources (DLNR) Administrative Rules, Title 13, Chapter 183, Sections 55 and 56, accept this letter and its attachment as an amendment to the previously submitted Plan of Operation (Plan) for the 25 MW Puna Geothermal Venture Project (PGV Project) power plant and associated geothermal wellfield. The PGV project is proposed for Geothermal Mining Lease R-2, which is located in the Kapoho section of the Kilauea Lower East Rift Geothermal Resources Subzone in the Puna District of the Island of Hawaii. The project will sell the generated electricity to the Hawaii Electric Light Company (HELCO) for use on the Island of Hawaii.

On December 8, 1986, Thermal Power Company (TPC), then the designated operator of the Puna Geothermal Venture partnership, submitted a Plan of Operation to the BLNR for the PGV Project. The BLNR deferred processing of the PGV Project Plan while TPC, at TPC's request, proceeded with the preparation of an Environmental Impact Statement (EIS) for the PGV Project. Subsequent to acceptance of the Final EIS for the PGV Project by the Hawaii County Planning Department, no further processing of the submitted Plan has taken place because the entire interest in the PGV partnership was purchased during the first half of 1988 by AMOR VI Corporation and AMOR VIII Corporation (AMOR Corporations), two wholly-owned subsidiaries of Ormat Energy Systems, Inc. of Sparks, Nevada (please refer to letters dated August 2, 1988, October 6, 1988 and October 24, 1988 to your office for additional information regarding Puna Geothermal Venture).

Since their purchase of all the interests to PGV and the PGV Project, the AMOR Corporations have reviewed the TPC design of the PGV Project to determine if it remains entirely appropriate. As a result of this design review, the AMOR Corporations have decided to alter several aspects of the PGV Project proposed by TPC to optimize projection operations and further reduce the potential for environmental impacts. Principal among these proposed changes is the use of back-pressure steam turbines, in combination with air-cooled binary cycle turbines, in place of the steam turbines and cooling towers proposed by TPC. This proposed power plant

101 Aupuni Street Suite 1014-B, Hilo, Hawaii 96720 • Phone (808) 961-2184 • Facsimile (808) 961-3531

configuration applies a closed cycle for the geothermal fluid, thus eliminating the need for cooling water. Besides essentially eliminating hydrogen sulfide emissions, most other environmental impacts from this project will be the same as those described in the PGV Project Final EIS because the AMOR corporations' proposed PGV Project will be located on the same site as the PGV Project proposed by TPC, and will use the same well pad locations and the same geothermal resource.

This amendment to the PGV Project Plan has been prepared to replace, in its entirety, the Plan of Operation for the PGV Project submitted to the BLNR in December, 1986. The amended Plan consists of this letter and a copy of the Geothermal Resource Permit (GRP) application amendment for this revised PGV Project, which was submitted to the Hawaii County Planning Department on December 30, 1988, as the GRP application amendment contains all the information required in Title 13, Chapter 183, "Rules on Leasing and Drilling of Geothermal Resources," Section 55, "Plan of Operation Required." The following concordance compares the information requirement of Section 13-183-55 with the sections of the Puna Geothermal Venture GRP application amendment:

"(1) The proposed location and elevation above sea level of derrick, proposed depth, bottom hole location, casing program, proposed well completion program and the size and shape of drilling site, excavation and grading planned, and location of existing and proposed access roads;"

The locations and elevations of the six proposed wellpads on which the 150-foot derrick will be placed are discussed in Section 3.2.1.1. Wellpads and Access Roads. This section also describes the size and shape of the drilling sites and the location of the existing and proposed access roads. Project elevations are discussed in Section 3.4. Elevation of Structures.

The proposed depth, bottom hole locations, casing program, and the proposed well completion program are discussed in Section 3.2.1.2. Well Drilling. Appendix B contains additional information on the well casing and well completion program. Information on injection casing is contained in Section 3.2.1.6. Geothermal Fluids Injection System.

Excavation and grading plans are presented in Section 3.6. Surface Disturbance.

"(2) Existing and planned access, access controls and lateral roads;"

The existing and planned access roads are presented in Section 3.2.1.1. Well Pads and Access Roads and Section 3.10.8.1. Traffic. Access control is discussed in Section 3.2.3.6. Fencing and in Section 3.10.6. Protection of Public Health and Safety.

"(3) Location and source of water supply and road building material;"

No water will be needed for power plant cooling. The location and source of water supply for service water is discussed in Section 3.3. Plot and Site Plans. No significant amount of road building materials will be needed for the project. Most access roads will be improved from existing agricultural roads, and only Wellpad F will require a new road.

"(4) Location of camp sites, air-strips, and other supporting facilities;"

The location of the temporary construction yard is shown on Figure 2-1. No air strip or other supporting facilities are proposed for the project.

"(5) Other areas of potential surface disturbance;"

Surface disturbance is discussed in Section 3.6. Surface Disturbance.

"(6) The topographical features of the land and the drainage patterns;"

Figure 3-2 is a topographical map of the project area. Drainage is described in Section 3.2.3.4. Site Drainage Facilities and Section 3.8. Geologic Report.

"(7) Methods of disposing of well effluent and other waste;"

Section 3.7. Disposal of Well Effluent and Other Waste discusses disposal of geothermal brines, condensate and noncondensable gases as well as other wastes. Further detail is provided in Section 3.2.1.6. Geothermal Fluids Injection System. Well testing effluents are discussed in Section 3.2.1.3. Well Testing.

"(8) A narrative statement describing the proposed measures to be taken for protection of the environment, including, but not limited to the prevention or control of:

(A) Fires,
(B) Soil erosion,
(C) Pollution of the surface and ground water,
(D) Damage to fish and wildlife or other natural resources,
(E) Air and noise pollution, and
(F) Hazards to public health and safety during lease activities.

Section 3.10. Environmental Protection is a written description of the measures to be taken to protect the environment. It includes the following subsections: 3.10.1. Fire Protection; 3.10.2. Erosion Control; 3.10.3. Protection of Sruface Waters and Groundwater; 3.10.4. Protection of Fish and Wildlife and other Natural Resources; 3.10.5. Control of Air and Noise Emissions; and 3.10.6. Protection of Public Health and Safety.

"(9) A geologist's preliminiary survey report on the surface and sub-surface geology, nature and occurrence of the known or potential geothermal resources, surface water resources, and ground water resources;"

Section 3.8. Geologic Report describes the surface and subsurface geology, the nature and occurrence of the known or potential geothermal resources, surface water resources and groundwater resources.

"(10) All pertinent information or data which the chairperson may require to support the plan of operations for the utilization of geothermal resources and the protection of the environment;"

The PGV project GRP contains additional details on the project, particularly in Section 3.2. Project Scope and Description. If the chairperson requires further information, it will be provided upon request.

"(11) Provision for monitoring deemed necessary by the chairperson to insure compliance with these rules for the operations under the plan."

Section 3.12. Monitoring Plans lists the monitoring activities proposed by PGV to show compliance with regulations. This discussion includes the following subsections: 3.12.1. Meteorological and Air Quality Monitoring; 3.12.2 Noise Monitoring; 3.12.3. Biological Monitoring; and 3.12.4. Compliance with Regulations, including the DLNR regulations in Chapter 183.

The plot plan and other drawings have been reduced for ease of copying. Larger size drawings are available if the DLNR staff requires them for their review. In addition, fourteen additional copies of the attachment to this letter, the PGV Geothermal Resource Permit application amendment, have been delivered under separate cover to the staff of the DLNR to facilitate the BLNR's review of the Plan.

Please do not hesitate to contact me if you have questions concerning the PGV Project or if we can be of any assistance in your timely review and approval of the Plan of Operation.

Sincerely yours,

AMOR VIII Corporation

Maurice A. Richard

by Maurice A. Richard
its Designated Agent

cc:
M. Tagomori - DLNR
D. Lum - DLNR

S. Oho
D. Low

1505

ORMAT®

RECEIVED

'89 JUL 10 A9:38

DIV. OF WATER & LAND DEVELOPMENT

June 30, 1989
Reference No. 89241

Mr. William W. Paty, Jr.
Chairperson
Board of Land and Natural Resources
State of Hawaii
Department of Land and Natural Resources
Kalanimoku Building
1151 Punchbowl Street
Honolulu, Hawaii 96813

Re: Application for Permit to Drill Geothermal Well Kapoho State 3 - State Geothermal Mining Lease R-2

Dear Mr. Paty:

In accordance with the Department of Land and Natural Resources Administrative Rules, Title 13, Chapter 183-65, Puna Geothermal Venture hereby submits the enclosed application for a permit to drill geothermal well Kapoho State 3, to be drilled from proposed wellpad E of the Puna Geothermal Venture Project, as approved in the Plan of Operation on March 10, 1989 by the Board of Land and Natural Resources.

Your timely consideration and approval of this application would be appreciated. Please do not hesitate to contact this office if you have any questions, or desire any additional information, regarding this request.

Sincerely,

Maurice A. Richard
Hawaii Regional
Development Manager

Enclosure

cc:
D. Carey, EMA w/enclosure

PUNA GEOTHERMAL VENTURE

☐ 101 Aupuni Street Suite 1014-B, Hilo, Hawaii 96720 • Telephone (808) 961-2184 • Facsimile (808) 961-3531
☐ 610 East Glendale Ave., Sparks, Nevada 89431-5811 • Telephone (702) 356-9111 • Facsimile (702) 356-9125

APPLICATION FOR PERMIT TO DRILL PROPOSED GEOTHERMAL WELL KAPOHO STATE 3 ON RESERVED LANDS, KAPOHO, PUNA, HAWAII

Complying with Department of Land and Natural Resources (DLNR) Administrative Rule, Title 13, Chapter 183, Subchapter 65, Puna Geothermal Venture (PGV) herewith makes application for Permit to Drill for approval by the Hawaii Board of Land and Natural Resources.

1. Applicant:

   Puna Geothermal Venture
   101 Aupuni Street
   Suite 1014-B
   Hilo, Hawaii 96720
   (808) 961-2184

   PUNA GEOTHERMAL VENTURE 06/30/89.

   By: Maurice Richard

   Maurice Richard
   Hawaii Regional Development Manager
   Puna Geothermal Venture

   Owner of Mining Rights:

   Kapoho Land Partnership

   Land Owner:

   Kapoho Land and Development Company, Limited

2. Proposed well designation: Kapoho State 3 (KS-3) off Wellpad E.

3. The enclosed tax key map, Attachment I, designates the approximate location of the drillsite for KS-3 off Wellpad E located on State Geothermal Mining Lease R-2. The elevation at Wellpad E is approximately 620 feet above mean sea level. A survey of the wellpads for the PGV Project is being prepared at this time. The survey data will be submitted when it becomes available.

4. The proposed PGV Project geothermal well KS-3 has been designed to maximize the possibility of intersecting, below approximately 4,000 feet, near-vertical fractures which are generally aligned along the axis of the Lower East Rift Zone (LERZ) and

which carry geothermal fluids for the purpose of providing geothermal resources to power the PGV Project power plant, previously approved in the Plan of Operation approved March 10, 1988, by the Board of Lands and Natural Resources.

5. A detailed Well Drilling and Completion Program, a Drillsite Plan, and a Vertical Section of the Well for the KS-3 well are contained in Attachments II, III, and IV, respectively.

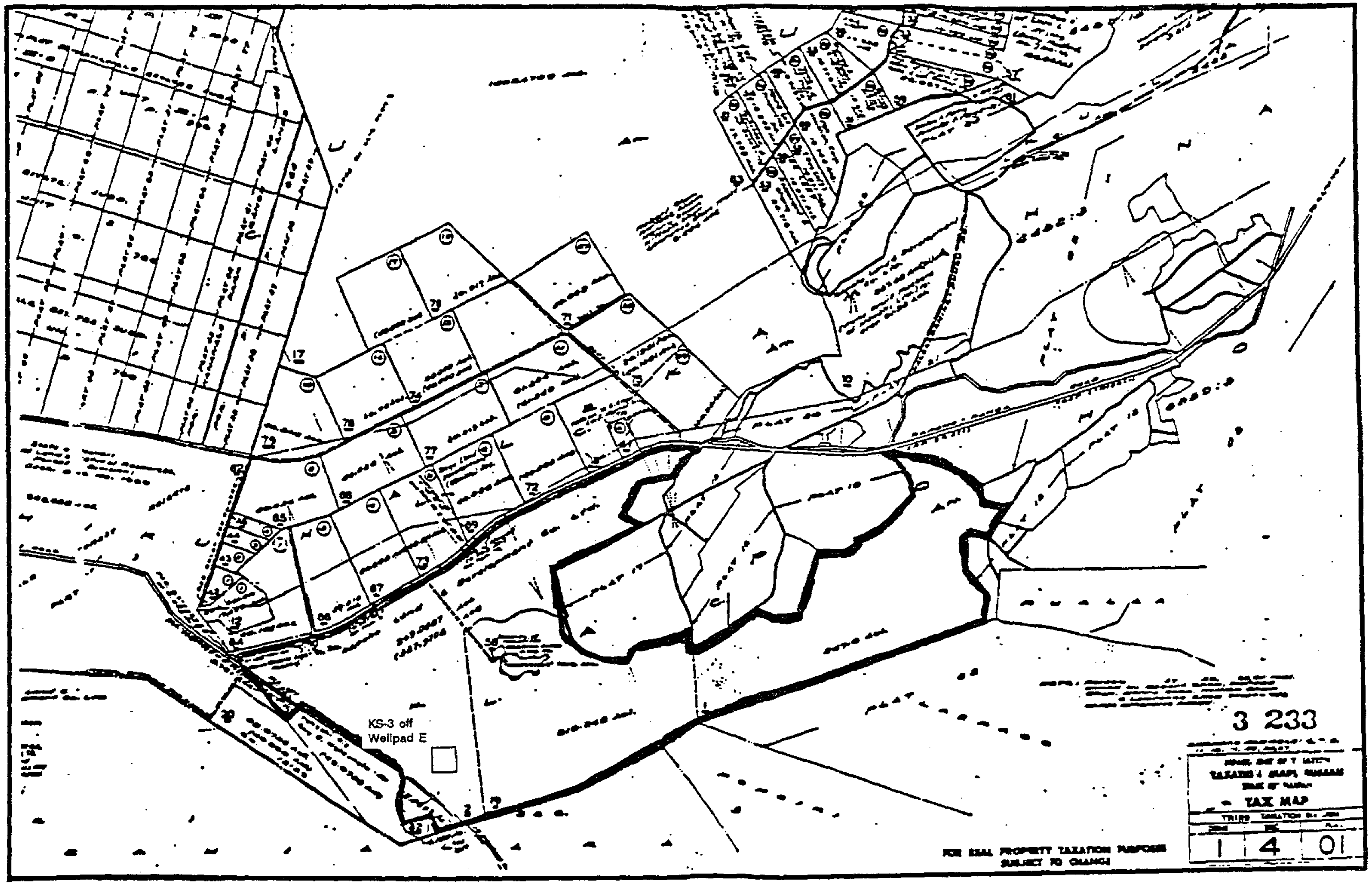
6. A multi-well drilling bond ($250,000) has previously been filed with the State of Hawaii.

7. Puna Geothermal Venture agrees to perform such drilling as outlined in this application and agrees to maintain the well in accordance with Title 13, Chapter 183, State of Hawaii, and all Federal and County geothermal regulations.

ENVIRONMENTAL M AGEMENT ASSOCIATES

TITLE: State of Hawaii - Tax Map Key Map

DATE: 06-28-89 ATTACHMENT I



Attachment II - Well Drilling and Completion Program

1. Well Design

The planned production well design is shown in Attachment IV.

2. Drilling Program

2.1 Prepare 10 ft. x 10 ft. x 8 ft. deep cement-rebar wellhead cellar on existing location. Set 30-inch conductor pipe through cellar floor.

2.2 Move in Drilling Contractor's rig; drill and set rathole.

(a) Notify Hawaii Board of Land and Natural Resources (BLNR) 24 hours prior to commencement of drilling.

(b) Confirm compliance with all permit requirements.

2.3 Spud hole with 17½ inch bit and mud drilling fluid; drill into top 20 feet of ground water zone. Stop and sample ground water.

2.4 Drill ahead to 800 foot depth. Open hole to 26 inch. Control loss of circulation (LOC) with loss circulation material (LCM); cement severe lost circulation zones if required.

2.5 Run 20 inch, 94 pound K-55 Buttress coupled casing to 1000 feet. Single stage cement with 40 percent silica flour; use appropriate excess slurry. Be prepared to cement the 20-30 inch annulus with from the surface. Hold casing in tension during annular cement job. Wait on cement (WOC) 8 hours.

2.6 Install 20 inch blow-out prevention equipment (BOPE) consisting of 20" casing head flange with 2 each 3" outlets for kill line and blow down line, 20" annular preventer and top mating flange and pitcher nipple assembly. Notify the Chairman of the BLNR in advance of the BOP test so that a designated representative can witness the test.

Test BOP assembly to 500 psig. Enter test results on contractor and operator daily reports.

2.7 Install mud logging service before drilling out 20" casing. Record: continuous mud in and out temperatures, H_2S, CH_4, CO_2, lithology, and drilling rate. Have pit level indicator and intercom to driller stations. Catch four sets of 50 gram dry sample every 20 feet. Make daily copies of the mud log, keeping one copy up to date and available on site.

2.8 Drill 17½ inch hole to 2200 foot depth with mud drilling fluid. Survey wellbore every 200 feet, or on bit change. Use LCM or cement to control LOC as necessary.

2.9 Run 13 3/8 inch, 61 pound K-55 NEW VAM casing to 2200 feet. Cement with 2200 cubic feet cement mixed 1:1 perlite, 40% silica flour, followed by 320 cubic feet cement mixed with 40% silica flour (note; provides for 100% excess). WOC 12 hours. If annular cement placement (top job) is needed hold casing in tension until final WOC is finished (i.e. do not release casing until cement is set at surface).

2.10 Install 13 5/8 inch BOPE consisting of the following items: 13 3/8" 900# casing head flange, 13 5/8" 3000 psi double gate BOP, 3000 psi double gate BOP, 3000 psi annular preventer, mating flange and riser with pitcher nipple.

Hook up kill lines and blow down lines. Casing head welding to be performed with pre- and post-flange heating by a certified welder.

Notify the Chairman of the BLNR in advance of BOP test so that a designated representative can witness the test.

Pressure test BOP assembly to 1000 psig. Record results on contractor and operator's daily reports.
Confirm drill site location and operation of all H_2S safety equipment. Put all drill site personnel through H_2S safety review including equipment downing by each person.

2.11 Drill out cement with 12¼ inch mill tooth bit. Pull out of hole, pick up button bit and drill 12¼ inch hole to 2500 feet with mud. Run deviation survey every 200 feet.

2.12 Pull out of hole and pick up 12¼ inch directional type button bit, mud motor, 4° bent sub, monel drill collar and additional collars and drill pipe as needed. Build angle at 2-3° per 100 feet in desired direction for approximately 100 - 200 feet with mud motor. Pull out of hole and pick up bottom hole assembly with 12¼ inch button bit, near bit reamer, 2 each 9" drill collars, string stabilizer, shock sub, additional 9" and 8" drill collars, heavy weight drill pipe as needed. Build hole angle to 16° and hold to 4000 feet TVD. Run deviation and direction surveys as necessary (every 20 to 100 feet). Keep mud motor on location and use as necessary to maintain angle and hole direction. Maximum dog leg to be 2°/100 feet. Use soft banded drill pipe for drill pipe that is located inside the 13 3/8 inch casing. Ream hole as necessary as judged by several short trips and deviation data. Use LCM or cement to control LOC as necessary.

2.13 Run 9 5/8 inch, 47 pound, C-90, VAM-AF (or equivalent) casing to bottom of 12¼ inch hole (±4000ft). Use centralizers every 120 feet through deviated portion of hole. Cement with 1850 cubic feet cement mixed with 1:1 perlite, 40% silica flour followed by 100 cubic feet cement mixed with 40% silica flour (provides for 100% excess). Wait on cement 12 hours. If annular (top) job is needed, hold casing tension until cement is set to surface.

2.14 Install wellhead assembly and BOPE.

If aerated mud or aerated water drilling is planned, wellhead and BOP will consist of 13 3/8" x 9 5/8", 900# WKM type S expansion spool (or equivalent), 10" 900# gate valve, 10" 3000 psi single gate BOP with steel pipe ram, 10" 3000 psi banjo box with 10" 3000 psi hydraulically actuated throttle valve on banjo box side outlet, 10" 3000 psi x 13 3/8" 3000 psi spool, 13 3/8" 3000 psi double gate BOP with steel pipe ram and blind ram, 13 3/8" 3000 psi annular preventer, and rotating head on top.

If mud or water drilling is planned, assembly will consist of 13 5/8" x 9 5/8" expansion spool, 10" valve as above, 10" x 13 3/8" spool and 13 3/8" double gate BOP and 13 3/8" annular preventer, mating flange and riser with pitcher nipple.

Notify the BLNR and test BOP.

2.15 Pick up 8½" mill tooth bit and drill out cement from casing. Pull out of hole, pick up bottom hole drilling assembly. Drill 8½" hole with aerated mud or aerated water (or mud/water) to ±7000 feet. Take directional surveys approximately every 100-150 feet. Condition hole and make several short trips to insure no fill on bottom of hole.

2.16 Pull out of hole and pick up ±3070 feet of 7" 29#/ft-L80 BT&C slotted casing with double slip liner hanger and 7" tieback set on top, and 7" guide shoe on bottom. Casing to be slotted from 4000'- 6950'. Set liner hanger at ±3880 feet (120' above bottom of 9 5/8" casing). Leave approximately 50' of open hole below bottom of casing for thermal expansion and debris.

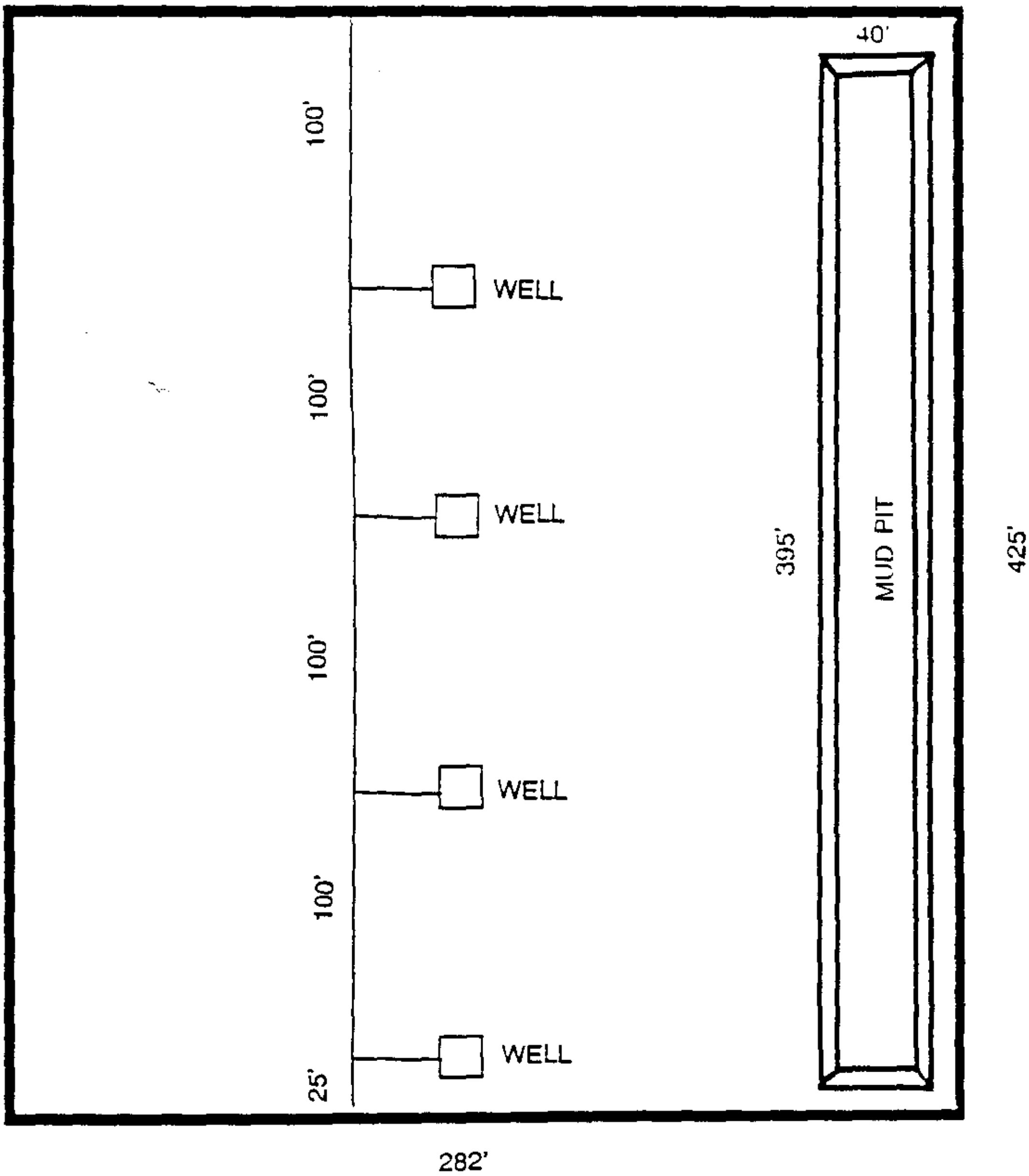
2.17 Run in hole with 3 1/2" drill-pipe and circulate out mud with water.

2.18 Rig down BOP and nipple up wellhead consisting of [expansion spool and one 900# 10" gate valve were attached in (2.14) above] 1 additional 900# 10" gate valve, 10" 900# flow tee with 900# 10" gate valve on side outlet and 3" 900# swab valve on top of tee.

ENVIRONMENTAL MANAGEMENT ASSOCIATES

TITLE: Wellsite Plan

DATE: 06-28-89 ATTACHMENT III

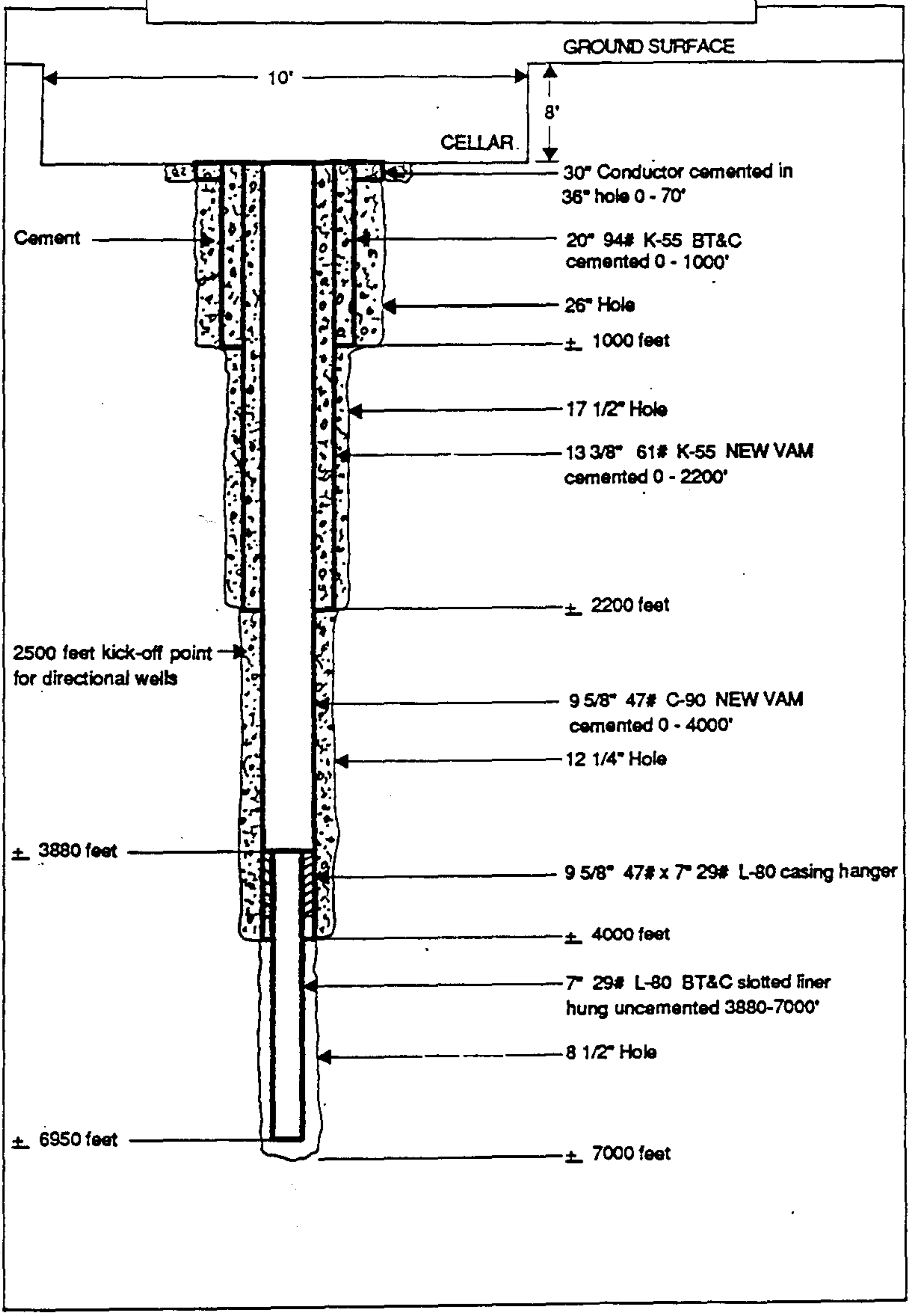


K906292A.840

ENVIRONMENTAL MANAGEMENT ASSOCIATES

TITLE: Vertical Section of the Well

DATE: 06-28-89 ATTACHMENT IV



JOHN WAIHEE
GOVERNOR OF HAWAII

WILLIAM W. PATY, CHAIRPERSON
BOARD OF LAND AND NATURAL RESOURCES

LIBERT K. LANDGRAF
DEPUTY

AQUACULTURE DEVELOPMENT PROGRAM
AQUATIC RESOURCES
CONSERVATION AND ENVIRONMENTAL AFFAIRS
CONSERVATION AND RESOURCES ENFORCEMENT
CONVEYANCES
FORESTRY AND WILDLIFE
LAND MANAGEMENT
STATE PARKS
WATER AND LAND DEVELOPMENT

STATE OF HAWAII
DEPARTMENT OF LAND AND NATURAL RESOURCES
P. O. BOX 621
HONOLULU, HAWAII 96809

GEOTHERMAL WELL MODIFICATION PERMIT

Kapoho State 1-A
Puna, Hawaii

TO: Puna Geothermal Venture
101 Aupuni Street, Suite 1014-B
Hilo, Hawaii 96720

Your application dated May 22, 1989, for a permit to modify Geothermal Well Kapoho State 1-A, is approved:

Well Designation: Kapoho State 1-A
Location: TMK 1-4-01:02, Kapoho, Puna, Hawaii
Mining Rights: Kapoho Land Partnership, under State Geothermal Resource Mining Lease R-2
Subleased to: Puna Geothermal Venture
Operator: ORMAT/AMOR VIII Corporation
Ground Elevation: 619 ft.
Total Depth: 6,505 feet

You are hereby granted permission to modify Geothermal Well Kapoho State 1-A by installing a temporary cement plug in the wellbore casing. Modification of the well shall be completed in accordance with the following conditions:

(1) The 150-foot cement plug shall be set in the 9-5/8" casing from a depth of 3,800 feet to 3,650 feet. A sinker bar shall be run into the casing to the top of the cement plug to verify the depth of the cement.

(2) Class "G" cement shall be used in the plugging operations and shall contain a high temperature resistant admix.

(3) After it has been verified that the cement plug has been set to the approved depth and thickness, the operator shall conduct a casing pressure test to evaluate the integrity of the casing string. Minimum casing test pressure shall be approximately one-third of the manufacturer's rated internal yield pressure and shall be applied for a period of thirty minutes.

(4) If a drop of more than ten percent of the casing test pressure is recorded, the operator shall then run a caliper log and/or other appropriate well test to evaluate if the casing is defective and if corrective measures will be required before commencing any further operations.

(5) A well completion report and an as-built drawing of the well modification shall be filed with the Department within six months after completion of the well modification.

(6) A well test report showing the results of the prescribed casing tests conducted, shall be submitted to the Department for review within sixty days after completion.

(7) The applicant shall obtain the Chairperson's approval prior to the execution of any contemplated changes in the modification program.

(8) All work shall be performed in compliance with the Department's Administrative Rules (Chapter 13-183), and all other applicable Federal, State, and County laws, ordinances, rules and regulations.

(9) The applicant, its successors and assigns, shall indemnify and hold the State of Hawaii harmless from and against any loss, liability, claim or demand for property damage, personal injury and death arising out of any act or omission of the applicant, assigns, officers, employees, contractors and agents under this permit or relating to or connected with the granting of this permit.

(10) The applicant shall notify the Division of Water and Land Development, in writing, of the date of the start of work.

(11) The bond covering the well shall remain in full force and effect until the well is properly abandoned and the surface properly restored.

(12) This permit shall expire 365 days from the date of issuance.

for [signature]

WILLIAM W. PATY, Chairperson
Board of Land and Natural Resources

6-16-89

Date of Issuance

JOHN WAIHEE
GOVERNOR OF HAWAII

STATE OF HAWAII
DEPARTMENT OF LAND AND NATURAL RESOURCES
P. O. BOX 621
HONOLULU, HAWAII 96809

WILLIAM W. PATY, CHAIRPERSON
BOARD OF LAND AND NATURAL RESOURCES

LIBERT K. LANDGRAF
DEPUTY

AQUACULTURE DEVELOPMENT PROGRAM
AQUATIC RESOURCES
CONSERVATION AND ENVIRONMENTAL AFFAIRS
CONSERVATION AND RESOURCES ENFORCEMENT
CONVEYANCES
FORESTRY AND WILDLIFE
LAND MANAGEMENT
STATE PARKS
WATER AND LAND DEVELOPMENT

JUN 5 1989

Mr. Duane Kanuha
Director
Planning Department
County of Hawaii
25 Aupuni Street
Hilo, Hawaii 96720

Dear Mr. Kanuha:

Thank you for the opportunity to review and comment on the application for a Geothermal Resource Permit submitted by Puna Geothermal Venture (PGV).

We have no major objections regarding the 25 MW geothermal project proposed for the island of Hawaii, but would like to offer the following comments:

1) The PGV application states that up to a maximum of 500 gallons per minute (720,000 gal/day) of water may be required for re-injection operations to maintain injection flow and to provide a sufficient quantity of fluid to absorb the noncondensable gases. It is indicated that this supplemental water may be supplied by one or two wells developed near the plant site.

   The applicant (PGV) should be advised that pursuant to the Department of Land and Natural Resources' Administrative Rules, Chapter 13-168, a well construction and pump installation permit, in addition to a well completion report will be required for the construction of any proposed water well. Futhermore, the applicant shall be required to comply with all other applicable regulations identified within that chapter.

2) Pursuant to PGV's proposal to re-inject geothermal fluids and noncondensable gases back into the geothermal reservoir, and in response to community concerns regarding potential impacts to the ground water aquifer down gradient from the site, it is recommended that if water wells are to be developed, that they be strategically sited within the project area so that they may serve as monitor wells as well as sources of supplemental water.

   Placement of these supply wells down gradient from the injection well sites will allow for periodic sampling of the existing ground water aquifer and the monitoring of the proposed injection operations.

3) It is futher recommended that the applicant file monthly reports of re-injection data, including but not limited to, quantity of fluids injected, chemical composition, and any changes in injection pressures which may indicate that the injected fluid is no longer confined to the intended zone of injection.

4) All work shall be performed in accordance with the Department of Land and Natural Resources' Administrative Rules (Chapters 13-183 and 13-184), and all other applicable Federal, State, and County laws, ordinances, rules and regulations pertaining to the lands and permittee's operations including, but not limited to, all water and air pollution control laws, and those relating to the environment.

5) If any unanticipated sites or remains of historic or prehistoric interest (such as shell, bone, or charcoal deposits, human burials, rock or coral alignments, paving, or walls) are encountered during the applicants operation, the applicant shall stop work and contact the State Historic Preservation Office at 548-7460 or 548-6408 immediately.

Thank you again for the opportunity to comment on the subject application and should you have any questions, please contact Dan Lum at 548-7643.

Very truly yours,

for

WILLIAM W. PATY

WL

c - Sono

ORMAT®

May 22, 1989
Reference No. 89141S

Mr. William Paty
Chairman
Board of Land and Natural Resources
Kalanimoku Building, #130
1151 Punchbowl Street
Honolulu, Hawaii 96813

Subject: Well Modification Permit Request

Reference: Geothermal Well: Kapoho State #1-A
Geothermal Resources Mining Lease R-2
Location TMK 1-4-01:02 Kapoho, Puna District, Hawaii County Leased to Kapoho Land Partnership

Dear Mr. Chairman:

A Department of Land and Natural Resources (DLNR) permit exists for the drilling and completion of the reference well. Since the conclusion of drilling and flow testing in 1985, Kapoho State #1-A has been maintained in a shut-in status with periodical gas cap ventings and incineration or burning of the exhausted gases. Puna Geothermal Venture (PGV) has closely monitored this well and complied with DLNR reporting requirements.

Puna Geothermal Venture herewith submits a Well Modification Permit request consistent with Chapter 183 of Title 13, Subchapter 183-65-4.

The attached work description and well casing configuration drawing including the approximate location of the proposed cement plug is attached for reference.

In brief, the PGV request is based on a technical need to periodically service the wellhead assembly to maintain a high standard of reliability and integrity. This routine servicing process is also timed to fit within the overall 30 MW development schedule and expected County permitting approvals and related requirements now in progress.

PUNA GEOTHERMAL VENTURE

☐ 101 Aupuni Street Suite 1014-B, Hilo, Hawaii 96720 • Telephone (808) 961-2184 • Facsimile (808) 961-3531
☐ 610 East Glendale Ave., Sparks, Nevada 89431-5811 • Telephone (702) 356-9111 • Facsimile (702) 356-9125

Your early consideration and approval will be appreciated. Please contact the Hilo office of Puna Geothermal Venture if you or your staff have any questions about the above request.

Sincerely,

Maurice A. Richard
Hawaii Region
Development Manager

Attachment

MAR/ci

11 May 1989

Program to Temporarily Suspend KS-1A with Cement Plug

1) Purpose of Work

It will be at least a minimum of a year before KS-1A is needed for production service. Therefore PGV has decided to temporarily suspend the well by setting a 150 foot cement plug in the casing at 3000 feet. This will eliminate the need for further gas burns and will permit the wellhead to be serviced and the condition of the production casing to be checked in preparation for putting the well in service.

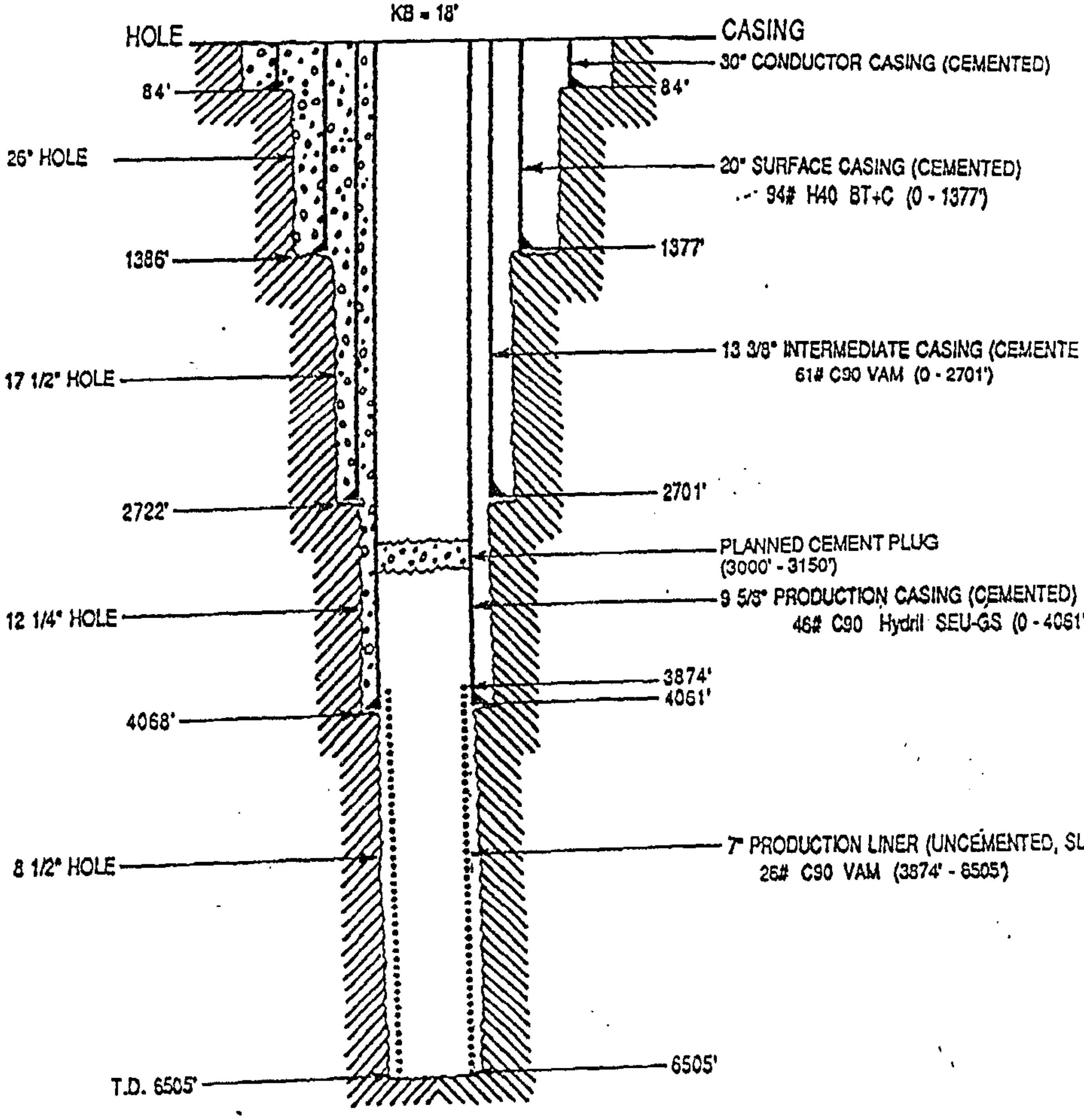
2) Plan of Work

The design of KS-1A showing the planned cement plug is shown in the attached figure. The setting depth of 3000 feet was chosen in order that the reservoir pressure beneath the plug will be balanced by the pressure exerted by the column of water in the wellbore above the plug. A rig will not be needed to carry out the work.
The operation is planned as follows :

1. Run sinker bar to 4500 feet.
2. Run a static pressure and temperature survey to 4500 feet.
3. Nipple-up pump to 3" side valve and kill well by slowly pumping cold water.
4. With the well killed run an 8" gauge ring to 3500 feet. Continue to pump water to maintain kill.
5. Run temperature survey to 4000 feet while maintaining kill to assess wellbore temperatures for cement slurry design.
6. Insert 9 5/8" bottom wiper plug through wellhead.
7. Pump 75 gallons (25 liner feet) water on top of plug.
8. Mix 60 cu ft (150 liner feet) geothermal cement and drop on top of water.
9. Insert top wiper plug and displace cement plug to 3000 feet with water (220 barrels).
10. Wait on cement 24 hours.
11. Run sinker bar to top of cement to check depth.
12. Shut-in wellhead and secure.

The operation is anticipated to take a total of 5 to 7 days.

KAPOHO STATE #1A WELL



Planned Cement Plug in KS-1A

State of Hawaii
DEPARTMENT OF LAND AND NATURAL RESOURCES
Division of Water and Land Development
Honolulu, Hawaii

March 10, 1989

Chairperson and Members
Board of Land and Natural Resources
State of Hawaii
Honolulu, Hawaii

Gentlemen:

Approval of Amendment to
Plan of Operations for 25 MW Geothermal Project,
<u>State Mining Lease No. R-2, Kapoho, Puna, Hawaii</u>

As required by State Mining Lease No. R-2 and Administrative Rules 13-183, Puna Geothermal Venture, sublessee, has submitted for Board approval an amendment to Plan of Operations for a geothermal project involving a 25 Megawatt power plant and associated well field.

The amended 25 MW project will be located in the Kapoho section of the Kilauea Lower East Rift Geothermal Resource Subzone in Puna, Hawaii, and will sell geothermal produced electricity to Hawaii Electric Light Co. for use on the Island of Hawaii. The amendments to the original Plan of Operations (December 1986) will reduce potential environmental impacts through the use of back-pressure steam turbines, air-cooled binary cycle steam turbines, and the injection of spent geothermal fluids and gases back into the geothermal reservoir at depth.

The completion date of the first phase which will produce 12.5 MW of electricity is expected to be late 1989. The second phase which will produce an additional 12.5 MW is expected to be completed by mid 1990.

<u>RECOMMENDATION</u>:

That the Board approve the amendment to Plan of Operations submitted by Puna Geothermal Venture for a 25 MW geothermal project on State Mining Lease No. R-2, subject to the following conditions:

(1) That Puna Geothermal Venture comply with all applicable statutes, ordinances, rules and regulations of the Federal, State, and County governments.

(2) Other terms and conditions as may be prescribed by the Chairperson.

Respectfully submitted,

MANABU TAGOMORI
Manager-Chief Engineer

APPROVED FOR SUBMITTAL

for WILLIAM W. PATY, Chairperson

RECEIVED

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DIV. OF WATER &
LAND DEVELOPMENT

GEOTHERMAL RESOURCE PERMIT

APPLICATION AMENDMENT

for the

PUNA GEOTHERMAL VENTURE PROJECT

Submitted by

PUNA GEOTHERMAL VENTURE

March 1989

ENVIRONMENTAL MANAGEMENT ASSOCIATES, INC.

GEOTHERMAL RESOURCE PERMIT

APPLICATION AMENDMENT

for the

PUNA GEOTHERMAL VENTURE PROJECT

Submitted by

PUNA GEOTHERMAL VENTURE
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March 1989

Prepared by

ENVIRONMENTAL MANAGEMENT ASSOCIATES, INC.
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PUNA GEOTHERMAL VENTURE PROJECT

GEOTHERMAL RESOURCE PERMIT APPLICATION AMENDMENT

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1. INTRODUCTION

The Puna Geothermal Venture (PGV) Project is a 25 MW (net) power plant and associated geothermal wellfield proposed for the Puna District of the Island of Hawaii. The project, located in the Kapoho section of the Kilauea Lower East Rift Geothermal Resources Subzone, will sell the generated electricity to the Hawaii Electric Light Company (HELCO) for use on the Island of Hawaii. Since the proposed project is located within an area where the designated Geothermal Resources Subzone underlies an agricultural state land use district, the project requires a Geothermal Resource Permit from the County of Hawaii.

The PGV Project is consistent with the stated objectives of providing energy self-sufficiency and diversifying Hawaii's economic base. The project will develop a new alternate energy source as well as provide additional information about the nature of the geothermal resource. These objectives are included in Hawaii's State Plan, the State Energy Functional Plan, and the County of Hawaii General Plan.

On December 10, 1986, Thermal Power Company (TPC), as then operator of the Puna Geothermal Venture partnership, submitted an application to the Hawaii County Planning Department (HCPD) for a Geothermal Resource Permit (GRP) for the PGV Project. TPC also requested that the HCPD be the accepting agency for an Environmental Impact Statement (EIS) that TPC would voluntarily prepare and submit for the PGV Project. Although the HCPD determined that there were no clear requirements for preparation of an EIS, the HCPD agreed to act as accepting agency for the EIS and deferred acceptance of the PGV Project GRP application until after acceptance of the EIS. The Final EIS for the PGV Project was accepted on December 28, 1987, although the Hawaii County Planning Director again noted that the PGV Project did not require the filing of an EIS. However, further processing of the GRP application has not occurred because the entire interest in the PGV partnership was purchased during the first half of 1988 by AMOR VI Corporation and AMOR VIII Corporation (AMOR Corporations), two wholly-owned subsidiaries of Ormat Energy Systems, Inc. of Sparks, Nevada.

Since the purchase, PGV has reviewed the previous design of the PGV Project to determine if it remains entirely appropriate. As a result of this design review, PGV has decided to alter several aspects of the previously proposed PGV Project design to optimize production operations and further reduce the potential for environmental impacts. Principal among these proposed changes is the use in the power plant of back-pressure steam turbines, in combination with air-cooled binary cycle turbines, in place of the steam turbines and cooling towers proposed by TPC. This currently proposed power plant configuration applies a closed cycle for the geothermal fluid, thus essentially eliminating hydrogen sulfide emissions during normal operations and eliminating the need for cooling towers. Most other environmental impacts from this revised PGV Project will be very similar to those of the previously proposed PGV Project because the revised PGV Project will use the same geothermal resource, the same geothermal wellpads, and the same power plant location as the previously proposed PGV Project.

This amendment to the GRP application has been prepared to replace, in its entirety, the GRP application submitted to the

Hawaii County Planning Department in December, 1986. For clarity sake, Chapter 2 of this application is a summary description of the revised PGV Project, drawing comparisons with the previously proposed PGV Project, as appropriate. A more detailed description of the revised PGV Project follows in Chapter 3, organized to follow the requirements of Rule 12, Geothermal Resource Permits, of the County of Hawaii Planning Commission Rules of Practice and Procedure. As required by Rule 12, Chapter 3 of this amended application also summarizes the PGV Project potential environmental impacts and mitigation measures. See Appendix A for a list of abbreviations used in this GRP Application.

2. PROJECT SUMMARY

The proposed PGV Project is located approximately 21 miles southeast of the city of Hilo in the Puna District of the Island of Hawaii (see Figure 2-1). The project will occupy about 25 acres of surface area within a dedicated 500-acre project area in the Kapoho section of the Kilauea Lower East Rift Geothermal Resource Subzone. The Kilauea Lower East Rift subzone was established in 1984 (Act 151) under Chapter 205, Hawaii Revised Statutes, which mandates the designation of geothermal resource subzones for geothermal exploration and development.

The proposed PGV Project is designed to generate 25 MW (net) of electrical energy from geothermal fluids produced from the Puna geothermal field. The project, which is planned for an operating life of 35 years, will consist of:

- ten (10) integrated back-pressure steam turbine and air-cooled binary cycle turbine power generating modules;
- up to 30 geothermal wells drilled from six (6) wellpads;
- brine and steam pipelines;
- pollution control equipment;
- a brine surge tank and holding pond;
- a switchyard;
- an office, warehouse, workshop, and control buildings;

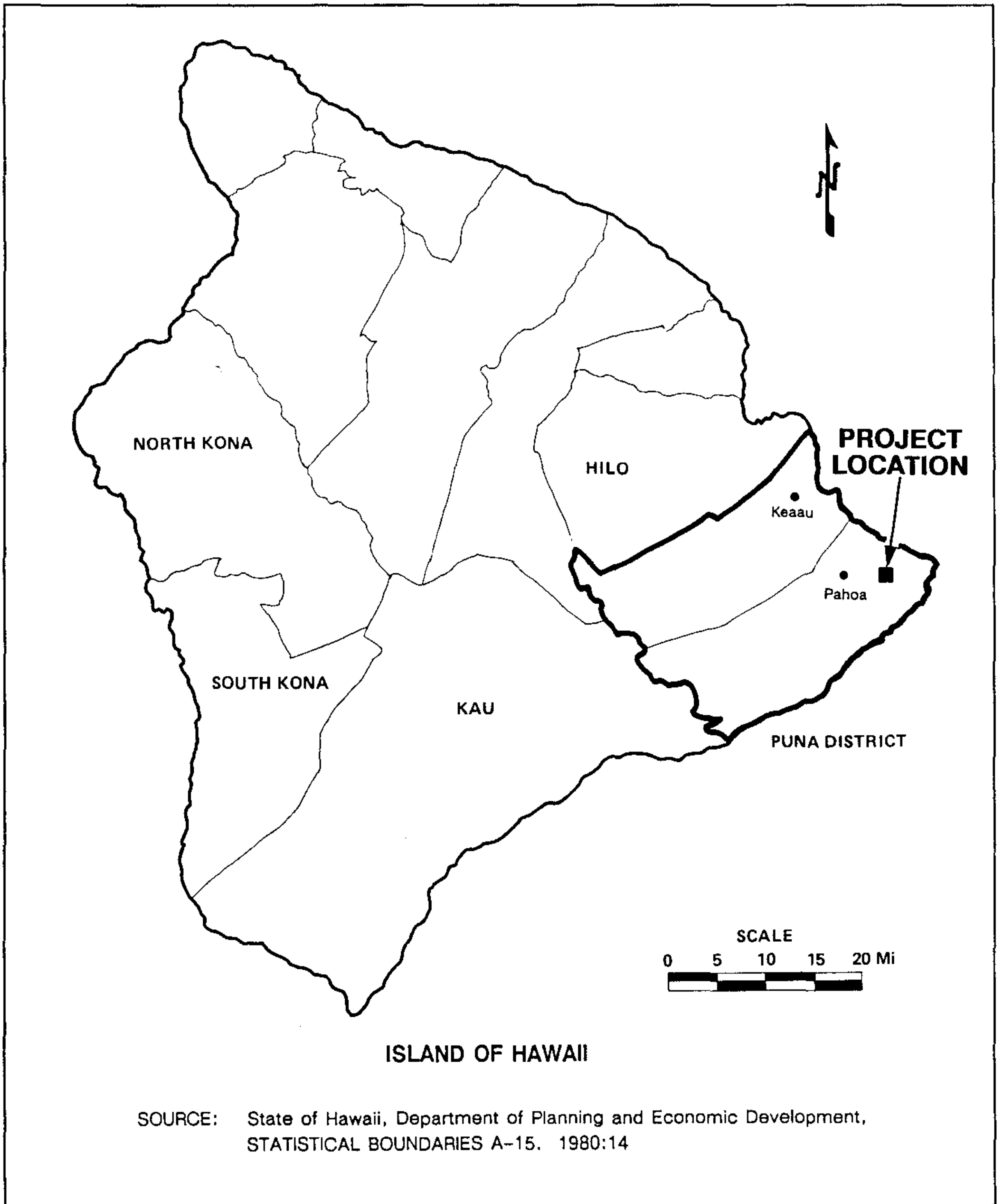


Figure 2-1. Location of the Puna District

- access roads; and

- auxiliary facilities such as air compressors, fire protection equipment, etc.

Figure 2-2 shows the locations of the major project facilities. The project will deliver 25 MW (net) to the switchyard, where the power will be purchased by HELCO to provide electricity to the Island of Hawaii.

The geothermal resources in the Puna geothermal area, located at depths generally greater than 4,000 feet, beneath impermeable caprock, are in excess of 600°F. The geothermal fluids produced from the Puna geothermal field are expected to contain a mixture of approximately 80 percent steam and 20 percent liquid at a pressure of about 200 psig and a temperature of about 390°F.

2.1.Wellfield Facilities

The proposed PGV Project will use the same geothermal wellpads and wellfield as the previously proposed PGV Project, as shown in Figure 2-2. Initially, the project is anticipated to require eight (8) production wells and two (2) injection wells, although the number of initial production wells may range from seven (7) to nine (9) and a third injection well may be necessary. Allowing for up to two (2) unusable wells (dry holes), nine (9) to fourteen (14) wells will need to be drilled for initial full-capacity operation. All wells will be drilled form up to six (6) wellpads. Additional makeup wells will need to be drilled over the 35-year economic life of the PGV Project, although all wells will be drilled from one of the six wellpads, and no more than a maximum of five (5) wells per wellpad will be

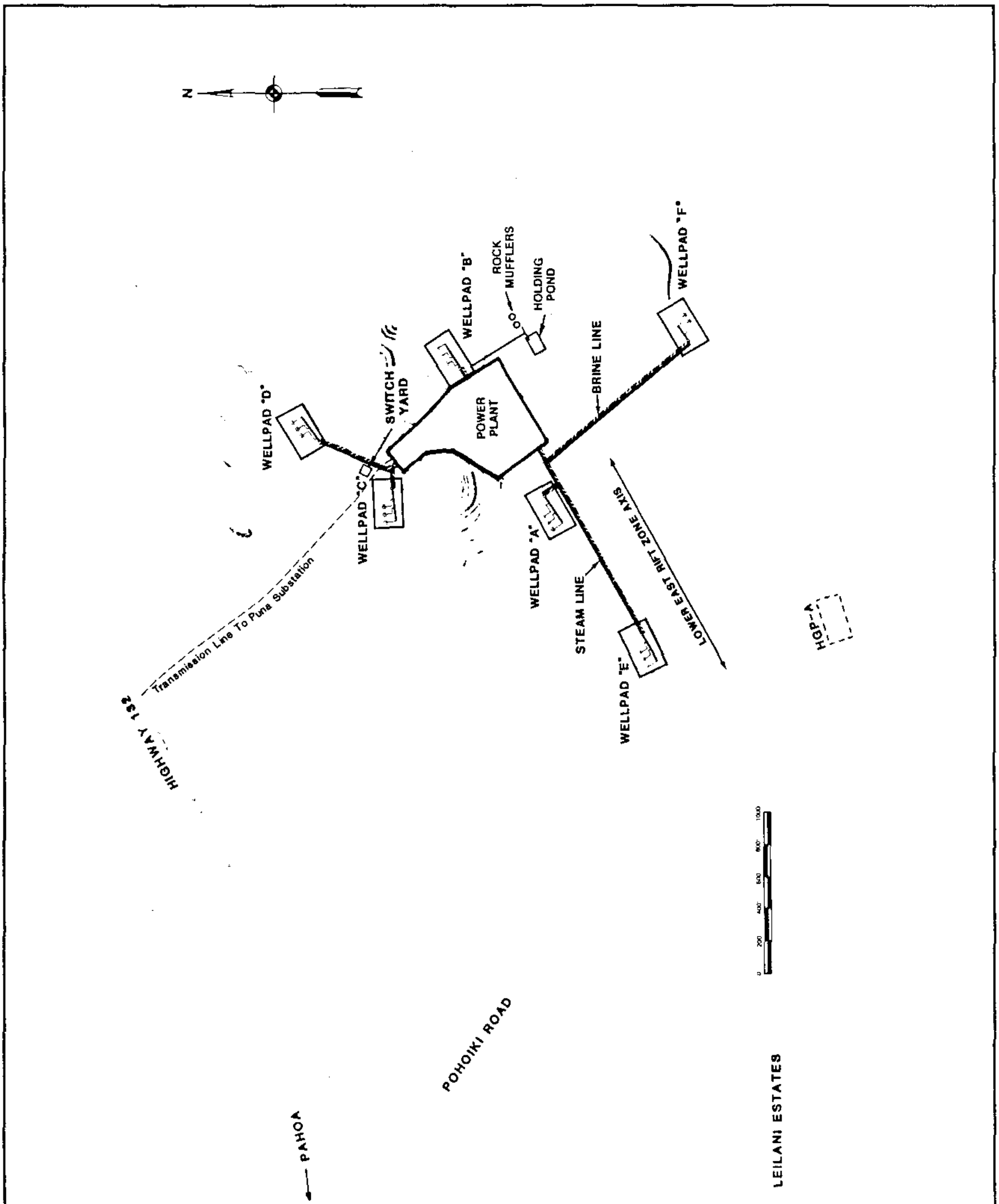


Figure 2-2. Puna Geothermal Venture Project Site Plan

drilled, for a maximum total of not more than 30 wells. Both production and injection wells will be drilled and cased down into the geothermal reservoir.

Each production well is expected to produce between 55,000 to 90,000 pounds per hour (lb/hr) of usable steam at a pressure of approximately 200 pounds per square inch gauge (psig) and a temperature of 387°F at the wellhead, as well as 14,000 to 22,000 lb/hr of geothermal brine and approximately 50 to 120 lb/hr hydrogen sulfide (H_2S).

Most drilling will be performed using drilling muds which produce negligible H_2S and particulate emissions, While drilling in the production zone, aerated water or aerated mud, may be used as the circulating medium. Occasional inadvertent releases of steam during drilling with aerated water or aerated mud will be limited to five (5) to ten (10) minutes, which will produce emissions of 7.0 lb H_2S or less during any one event. A cyclone separator will control particulate emissions during these steam releases.

Best Available Control Technology (BACT) will be applied during well testing. After venting to cleanout the well bore, each well will be connected to a separator which will partition the steam and gases from the brine. The steamline will be equipped with chemical abatement equipment to abate H_2S emissions by 95 percent. The steam will then be released through a rock muffler to muffle the noise.

All of the wells at each wellpad will be connected to a flash separator that will partition the geothermal brine from the geothermal steam and noncondensable gases. At least two wellfield gathering systems will be used to move the geothermal brine and geothermal steam to the power plant. A third pipeline may be needed to collect geothermal steam condensate produced by heat losses in the steam gathering lines. These pipelines will gather the appropriate fluid(s) and gases from each wellpad and will be routed to the power plant site together and, where practical, adjacent to the wellpad access roads. The steam will be delivered to the power plant system; the brine will be delivered to the brine surge tank for injection.

Under normal power plant operations, essentially all of the geothermal fluids produced by the production wells and all of the noncondensable gases will be returned to the geothermal reservoir through the injection wells. In the present design, after the steam has passed through the power plant system and been condensed, the steam condensate will be mixed with the geothermal brine from the brine surge tank. The noncondensable gases will then be injected into the condensate/brine mixture, and this recombined geothermal fluid will then be injected back into the geothermal reservoir.

2.2.Power Production

The PGV Project will generate up to 28.5 MW of electrical power so that 25 MW can be delivered to the HELCO electric grid system, with the balance of the power being consumed by the plant equipment. The actual amount of power generated will vary in response to steam quantities, atmospheric temperatures and other operating conditions.

Several changes have been proposed to the previous PGV Project power plant design to increase project reliability and flexibility, decrease construction time and reduce the potential for emission of air contaminants.

The design of the power plant has been modified by:

- utilizing ten (10) nominal 3 MW modular turbine-generating units instead of two (2) 15 MW turbine-generator units. Each module will contain the following turbine-generating equipment:

    - a nominal 1.8 MW back-pressure steam turbine,

    - a nominal 1.2 MW binary cycle turbine that generates additional electricity from the low-pressure steam leaving the back-pressure turbines, and

    - a common 3 MW generator;

- utilizing air-cooled condensers for the working fluid in the binary cycle instead of the water-cooled condensers, thus eliminating the cooling towers and the release of gases; and

- injecting <u>all</u> of the produced geothermal fluids (geothermal brine, steam condensate and noncondensable gases) back into the geothermal reservoir, thus eliminating all but negligible fugitive emissions of hydrogen sulfide during normal operations.

Figure 2-3 shows a simple schematic diagram of the PGV Project steam turbine/binary cycle power plant system.

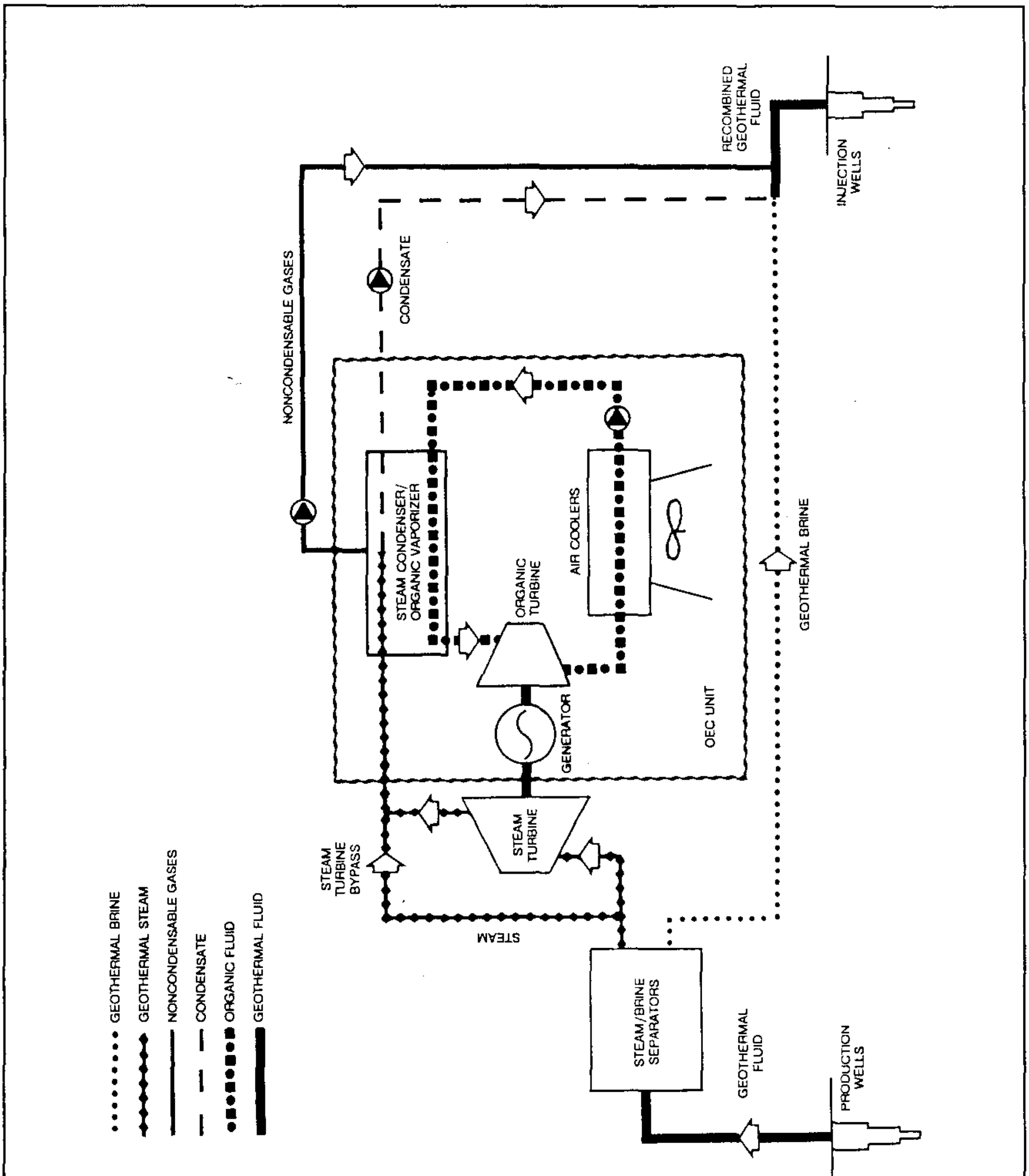


Figure 2-3. Simplified Process Flow Diagram

The proposed 1.8 MW modular back-pressure steam turbines operate much the same as the condensing steam turbines proposed in the previous PGV Project design, but the steam leaving the back-pressure turbines remains slightly above atmospheric pressure. Thus, the steam retains a significant amount of heat energy which is converted into electricity by the binary power generating units, known as Ormat Energy Converter (OEC) units. These OEC units, manufactured by Ormat Turbines, Ltd., apply principles and technologies well-tested in various industries and successfully applied in other geothermal fields throughout the world.

The OECs operate on the same basic principles as steam turbines, but use an entirely closed organic working fluid system instead of steam. OECs use the heat energy of the geothermal fluid to vaporize the organic working fluid (isopentane), which expands through a small turbine to generate electricity. The isopentane vapor is then condensed back into a liquid state in a condenser.

The PGV Project is also proposing that the binary working fluid condenser be cooled with air, rather than with water. Air cooling is also a well-tested technology that has been utilized in previous geothermal power plants. In this system, the binary working fluid vapor leaving the organic fluid turbines goes to the air coolers, where large fans force air across tubes containing the vapor. This air cools the binary working fluid vapor and condenses it into a liquid which is collected and routed back to the vaporizer and the turbines. Because air coolers have replaced the cooling towers, the PGV Project does not need to utilize the geothermal steam condensate as cooling tower makeup water. Thus, all the geothermal fluids (brine, steam condensate, and noncondensable gases) produced by the production wells can be injected back into the geothermal reservoir via injection wells.

The back-pressure steam turbine/binary cycle power plant is a closed system that, during normal operations, does not release any H_2S or other gases to the atmosphere. The geothermal fluids at the Puna field contains up to 1300 ppm H_2S and 600 ppm carbon dioxide (CO_2). A small fraction of the noncondensable gases will remain in the geothermal brine during the initial separation process. However, most of the noncondensable gases will be partitioned with the steam during the initial separation process, pass through the steam turbine, and be routed along with the low pressure steam to the heat exchangers in the OEC units. There the working fluid will condense the steam. The steam condensate will then be mixed with the brine for injection. The remaining gases, still under low pressure, will exit the OEC units and be compressed, and injected into the mixture of condensate and brine, and the recombined stream injected into the geothermal reservoir.

The process of dissolving H_2S and/or CO_2 into water is common practice in the field of chemical engineering. Injection of the combined fluid stream into the geothermal reservoir has been successfully demonstrated at the Coso geothermal field in California since July, 1987. Based on these results, the noncondensable gases produced from the Puna geothermal reservoir will be dissolved and entrained in the produced geothermal fluids by in-line mixing, and all of the produced fluids and gases will be injected into the geothermal reservoir. To ensure the reliability of the injection system, a spare pump, a spare compressor, and a spare injection well will be provided. A holding pond is provided to collect liquids for the unlikely event of an upset in the liquid injection system.

A major advantage of the proposed design is the ability of the OEC units to operate on high temperature steam when the steam portion of the module is not operating. Thus, when one or more steam turbines fail, the power plant can continue to operate, although at reduced rates; the actual rate of reduction will depend on the number of steam turbines that are shutdown. As long as the entire power plant uses at least 50 percent of the steam flow, there will be no emergency steam release.

To enable this mode of operation, a steam turbine bypass system will be installed on each steam turbine unit so that its OEC unit can operate even when the steam turbine portion is not in operation (such as during plant start-up). In this situation, the geothermal steam bypasses the steam turbine and enters directly into the OEC vaporizer, where it condenses as during normal operating conditions.

When the entire power plant is shut down, an emergency steam release facility will be used to release steam, treated with sodium hydroxide (NaOH) to remove 96 percent of the H_2S, through a rock muffler (which will reduce noise levels) while the wellfield production rate is being reduced to 50 percent of full flow. After this reduction, the power plant will emit less than 2 percent of full flow uncontrolled H_2S (98 percent control) until normal operation is resumed.

3. DETAILED DESCRIPTION OF PROPOSED ACTION

Planning Commission Rule 12-3 provides a detailed description of the information which must be contained in a Geothermal Resource Permit application. The discussion that follows is arranged to coincide with the order of Items 12-3(b)(2) parts (A) through (P). The relevant Rule 12 description is included at the beginning of each subsection.

3.1. Location and Description of Property

This subsection provides "a description of the property for which a permit is being requested to include the property's real property tax map key designation and a description of the property's location within the County" as required by Rule 12-3(b)(2) part (A).

The 500-acre PGV Project area, for which the PGV Project is requesting a Geothermal Resource Permit, is located in the Puna District of the County of Hawaii, approximately 21 miles southeast of the city of Hilo, in the Kapoho Section of the Kilauea Lower East Rift Geothermal Resource Subzone (see Figure 2-1). The entire PGV Project area was designated as a geothermal resource subzone in 1984 by Act 151 of the Hawaii legislature. The PGV Project area was one of three areas established as subzones since the landowners of these areas had already obtained State geothermal mining leases and developers of the lands had been issued County special use permits for geothermal development activities.

Specifically, the approximately 500-acre PGV Project area consists of the following properties, as identified by their Tax Map Key designations:

- TMK 1-4-01:2 (portion) containing approximately 300 acres
- TMK 1-4-01:3 (all) containing 3.741 acres
- TMK 1-4-01:19 (portion) containing approximately 200 acres
- TMK 1-4-01:58 (all) containing 0.0758 acres

This is the total area, surface and subsurface, over which PGV intends to conduct the PGV Project, although the actual permanent surface disturbance from the project will be limited to approximately 24.5 acres within this approximately 500-acre parcel (see Section 3.6). The 500-acre PGV Project area (see Figure 3-1) is contained entirely within an 816-acre parcel that PGV subleases from the Kapoho Land Partnership (KLP). The PGV sublease includes the right to develop the geothermal resources and utilize as much of the surface lands within the subleased lands as reasonably necessary to develop the geothermal resources, subject to KLP's right to develop non-competing uses. KLP holds the surface rights to the parcel and has obtained a State of Hawaii Geothermal Mining Lease (R-2), which includes the rights to the geothermal resource. KLP's State lease has been assigned to PGV.

The wellpad and power plant locations are situated on scrub vegetation and fallow fields. The dominant vegetation is non-native weedy species and abandoned papaya orchards. Much of the area within one mile of the power plant is covered by either the 1955 lava flow, fallow fields or Metrosideros forests. Scattered residences are found outside the project boundary.

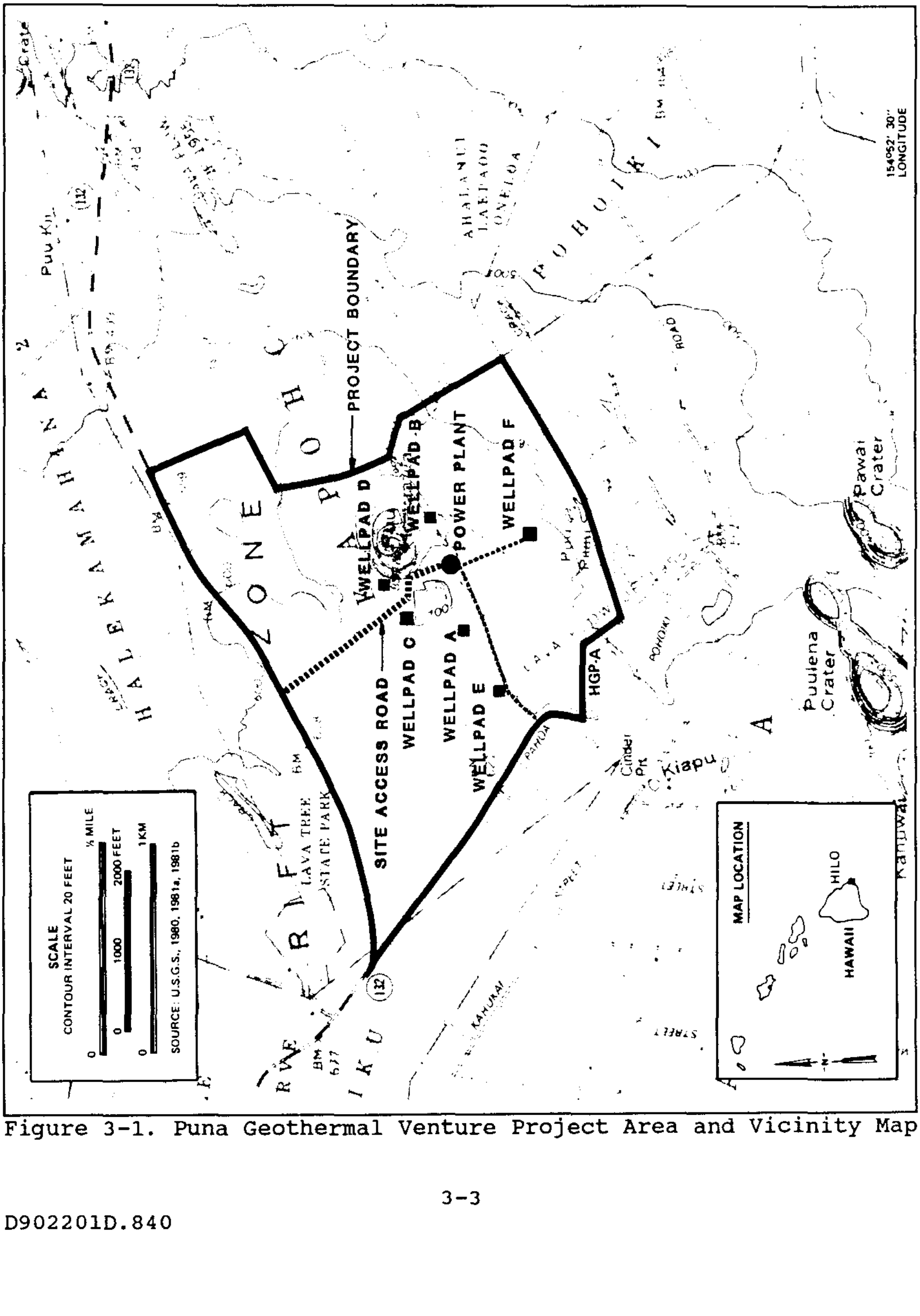


Figure 3-1. Puna Geothermal Venture Project Area and Vicinity Map

3.2. Project Scope and Description

This subsection provides "a written statement describing the scope of the planned activities and presenting the applicant's reasons for requesting the permit" as required by Rule 12-3(b)(2) part (B).

PGV is applying for a Geothermal Resource Permit in order to develop the Puna geothermal resource for the generation of electrical power to furnish 25 MW of electrical capacity to HELCO's energy grid system.

PGV seeks approval from the County of Hawaii Planning Commission for the construction of a geothermal power plant, associated wellfield and gathering system, and all roads, buildings, and facilities necessary for safe, effective development. A detailed description of the project is presented below.

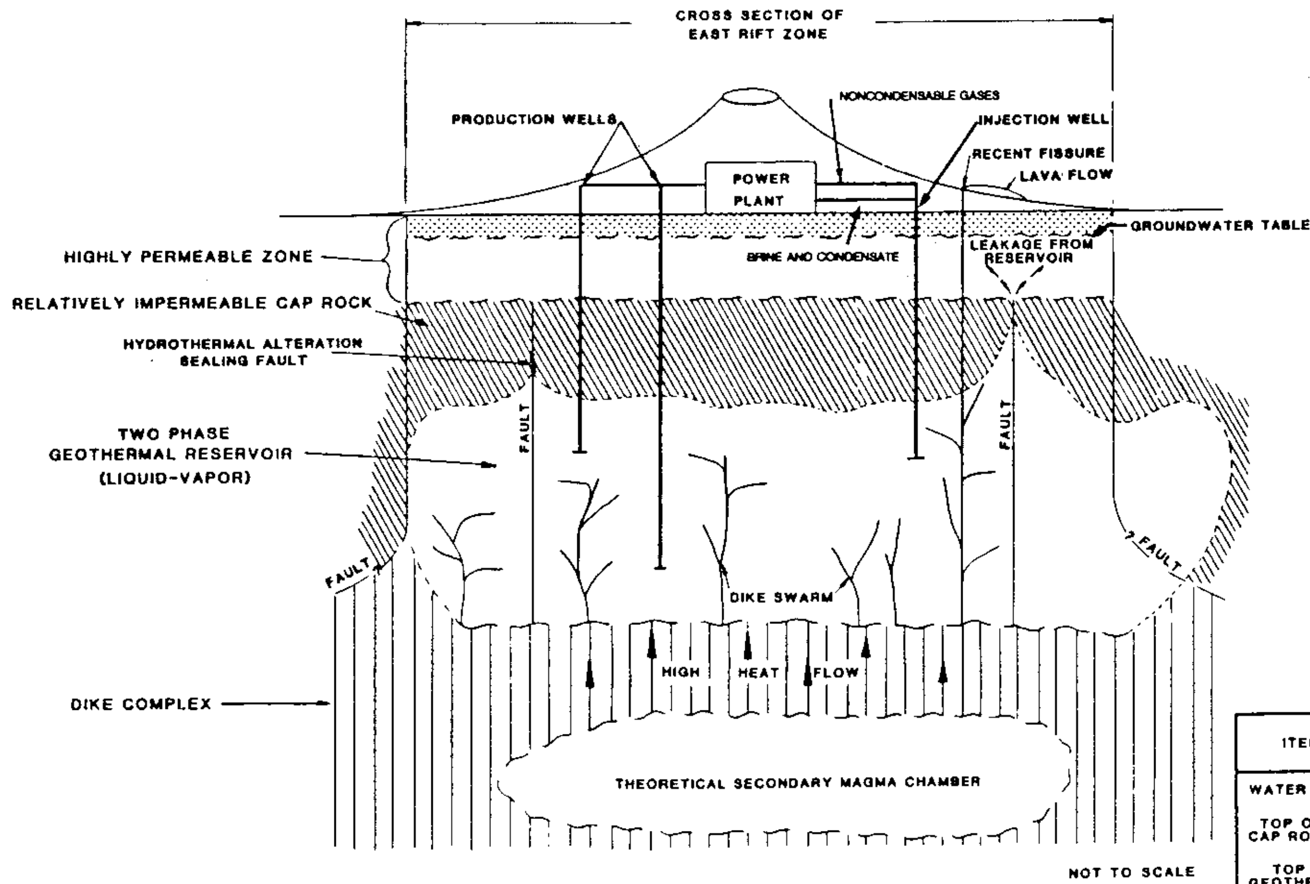
3.2.1. Geothermal Wellfield Facilities

3.2.1.1. Wellfield Development Plan

The PGV Project is located in a geologic region known as the Lower East Rift Zone (LERZ), found on the eastern flank of Kilauea Volcano. At depths below 8,000 feet beneath the surface features of the LERZ, a 5- to 15-mile wide dike complex is thought to exist, where temperatures approach 1,900°F, the melting point of basalt. A secondary magma chamber may be located within the LERZ beneath the geothermal reservoir. The series of dikes are thought to convey heat to the high-temperature geothermal reservoir, a system of vertical to near-vertical fractures which contains, below 4,000 feet, a two-phase geothermal resource with temperatures as high as 600°F. Overlying the high-temperature geothermal reservoir is a relatively impermeable layer of capping rock, generally at depths of between 4,000 and 2,500 feet below the surface, although both the upper and lower boundaries are variable and dependent upon the local permeability (fractures). A conceptual model of the Puna geothermal reservoir is presented in Figure 3-2.

To date, six deep test wells have been drilled in the general PGV Project area (see Figure 3-3). Four of the wells appear to have been drilled into the high-temperature Puna geothermal reservoir, as they encountered temperatures in excess of 600°F at depths below 4,000 feet: Kapoho State 1 (KS-1) and Kapoho State 1-A (KS-1A), drilled from PGV Wellpad A; Kapoho State 2 (KS-2), drilled from PGV Wellpad B, and the HGP-A well. Currently, KS-1 and KS-2 are suspended with cement plugs in their bores, and KS-1A is closed in (shut in). The fourth well, HGP-A, is currently producing steam for the 3 MW HGP-A demonstration plant, which is located immediately outside the PGV Project boundary, south of proposed PGV Wellpad E. The other two wells, Lanipuna 1 and Lanapuna 6, encountered lower temperatures and appear to be located on, and define, the southeast margin of the high temperature geothermal system in the immediate area.

The proposed PGV Project geothermal wellfield development plan has been designed to maximize the possibility of drilling geothermal production wells that intersect, below approximately 4,000 feet, these near-vertical fractures, which are generally aligned along the axis of the LERZ and which carry the geothermal fluids. To accomplish this, geothermal wells will be directionally drilled in general southeast and northwest



ITEM	DEPTH BELOW GRADE
WATER TABLE	~ 600′
TOP OF CAP ROCK	~ 2500′
TOP OF GEOTHERMAL RESERVOIR	~ 4000′

Figure 3-11 CONCEPTUAL MODEL OF THE PUNA GEOTHERMAL RESERVOIR

Figure 3-2. Conceptual Model of the Puna Geothermal Reservoir

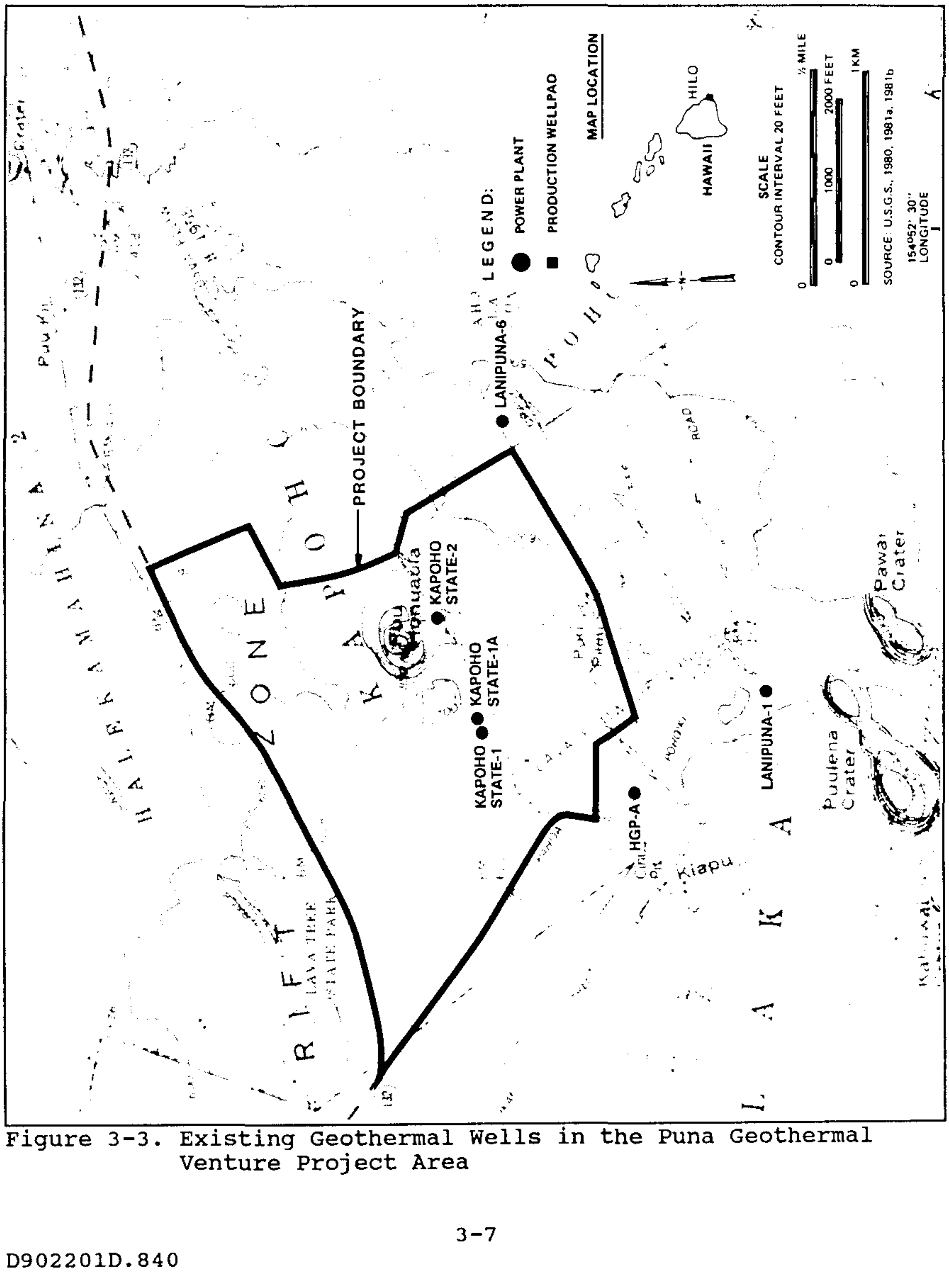


Figure 3-3. Existing Geothermal Wells in the Puna Geothermal Venture Project Area

directions from the six multi-well wellpads shown in Figure 3-4. As stated above, geothermal exploration wells have already been drilled from Wellpads A and B. The proposed sites for the four additional wellpads (Wellpads C, D, E and F) were selected on basis of proximity to the power plant, current knowledge of reservoir extent, optimal drilling targets, directional drilling experiences, and injection needs. In order to optimize wellfield production with low surface area requirements, these proposed wellpad locations may require relocation within the proposed 500-acre PGV Project area after additional drilling, production, injection, or other information becomes available. The approximate elevations of the wellpads in feet above mean sea level (AMSL) are given in Table 3-1.

Table 3-1. Geothermal Wellpad Elevations

Description	Elevation
Wellpad A	640 feet
Wellpad B	720 feet
Wellpad C	680 feet
Wellpad D	700 feet
Wellpad E	620 feet
Wellpad F	620 feet

Table 3-2 presents the current initial geothermal well development plan for the PGV Project. Based upon drilling and flow testing experience to date, and projections of future performance, PGV has designed its wellfield for wells that produce approximately 62,500 lb/hr steam, with any individual

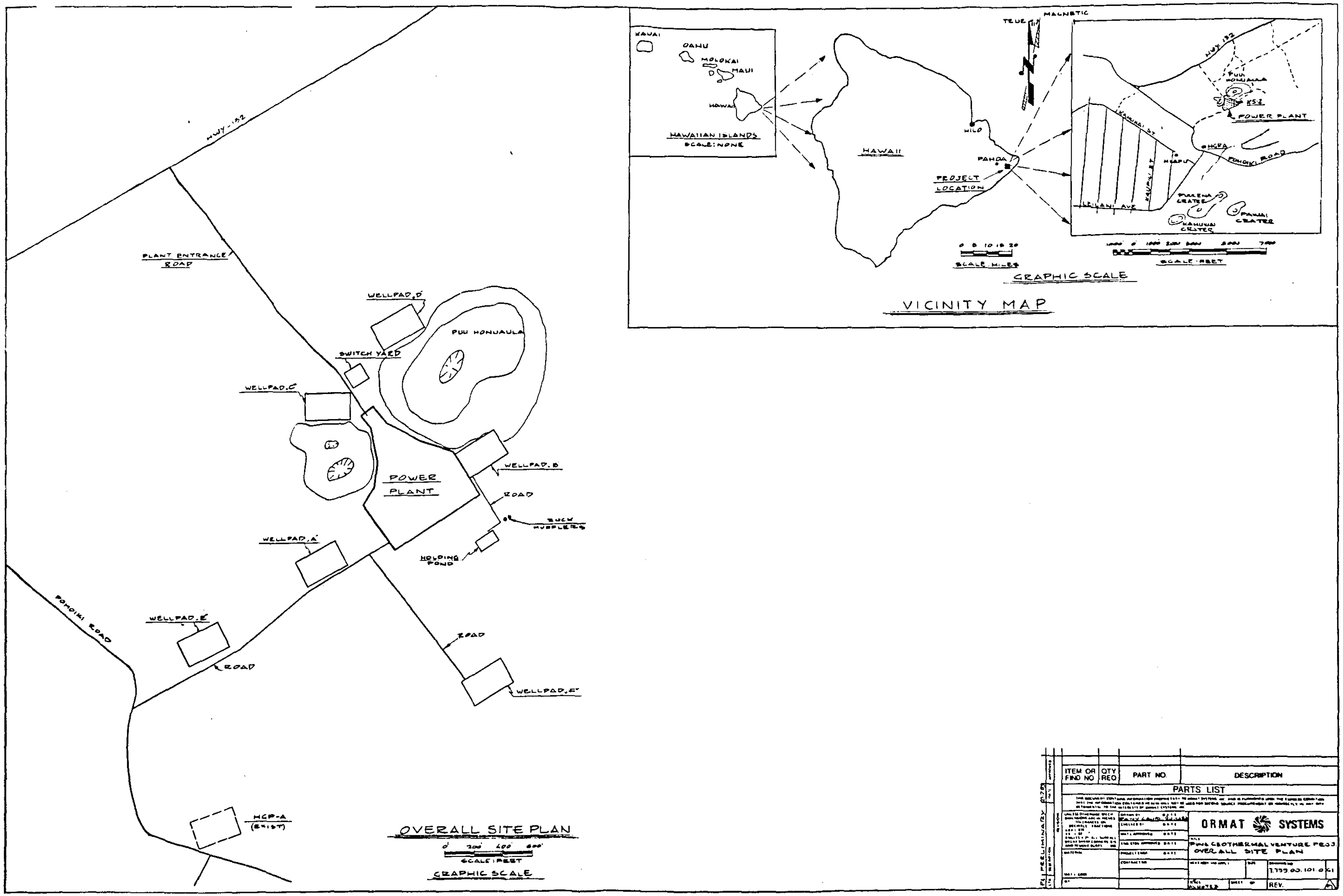


Figure 3-4

Figure 3-4. Puna Geothermal Venture Project Overall Site Plan (Dwg. No. 7.799.00.101.0)

Table 3-2. Initial Well Development Plan

Type of Well	Anticipated	Range
Production Wells	8	7 - 9
Injection Wells	2	2 - 3
Allowance for Unusable Wells	0	0 - 2
Total Initial Wells	10	9 - 14

well producing between 55,000 and 90,000 lb/hr steam. Thus, PGV anticipates that eight (8) production wells will be needed to supply the anticipated steam requirements of 500,000 lb/hr for the power plant at full load, although depending on the actual production rate of the wells, seven (7) to nine (9) wells may eventually supply the steam requirements of the project. To dispose of the produced geothermal brine and geothermal steam condensate, two (2) wells have been planned as geothermal injection wells; one for ongoing use and one as a spare, although a third well may be necessary. Some wells with poor production characteristics may ultimately be used as injection wells, but it is currently anticipated that wells will be drilled specifically for the injection of geothermal fluids. Additional wells are also included in the initial geothermal well development plan to allow for the possibility of drilling unsuccessful wells which terminate in impermeable rock.

Once sufficient wells are drilled to supply the initial production and injection requirements of the power plant, additional wells will be drilled as needed to supplement replace wells which have lost production or injection capacity, which is a normal occurrence in all geothermal fields. Over the 35-year life of

Table 3-3. Anticipated Initial Geothermal Well Development Sequence

	Wellpad and Well Number	
Drilling Sequence	Production Wells	Injection Wells
Existing	A-2 (KS-1A)	
First	E-1	F-1
Second	E-2	F-2
Third	A-3	F-3
Fourth	A-4	
Fifth	D-1	
Sixth	D-2	
Seventh	E-3	
Eighth	E-4	
Ninth	B-2	

the PGV Project, it may be necessary to drill as many as 30 geothermal wells, the maximum number of wells which can be drilled from the six proposed wellpads (see Section 3.2.1.2).

The currently anticipated well development sequence for the initially required production and injection wells is shown in Table 3-3. The first well listed in Table 3-3, Well A-2 (KS-1A), already exists. The other wells in the project area, A-1 (KS-1) and B-1 (KS-2), are cemented in and will not be used. The drilling sequence proposed for the next seven wells reflects the overall strategy to drill wells with the highest resource confidence level first, followed progressively by those in more uncertain areas, with a significant consideration given to minimizing the number of times the drilling rig must move between wellpads. This proposed drilling sequence will be reviewed and changed, if necessary, after the completion of each well as additional information is gathered about the geothermal reservoir. At present, of the existing three wells, only KS-1A will be used as a production well for the PGV Project. Further, no wells are currently planned for Wellpad C in the initial development, and this wellpad will be kept in reserve for the drilling of makeup wells when necessary.

The specific bottom hole drilling target for each well cannot be determined precisely with the reservoir information now available, but, because wells will be directionally drilled from the wellpads, the bottom hole locations may be up to 1,500 feet horizontally distant from the wellhead. However, all bottom hole locations will remain within the 500-acre PGV Project area boundary. Specific bottom hole targets will be identified for each geothermal well in the drilling permit application which is required by the Hawaii State Department of Land and Natural Resources (DLNR) to be submitted to, and approved by, the DLNR prior to commencing drilling.

3.2.1.2.Wellpads and Access Roads

Each wellpad will measure approximately 300 by 400 feet, and will be designed to accommodate the drilling of up to five wells (see Figure 3-5). The wellheads will be placed in cellars approximately 10 by 10 by 8 feet deep (see Figure 3-6), and will be set about 50 to 100 feet apart within the wellpad. Each wellpad will be a leveled area large enough to accommodate the drilling rig and all the drilling support equipment, structures and crews. Each site will be engineered to support the drilling equipment and to keep drilling effluent contained onsite and separate from any natural drainage. Each wellpad will have drilling mud pits; sumps with gently sloped walls used to

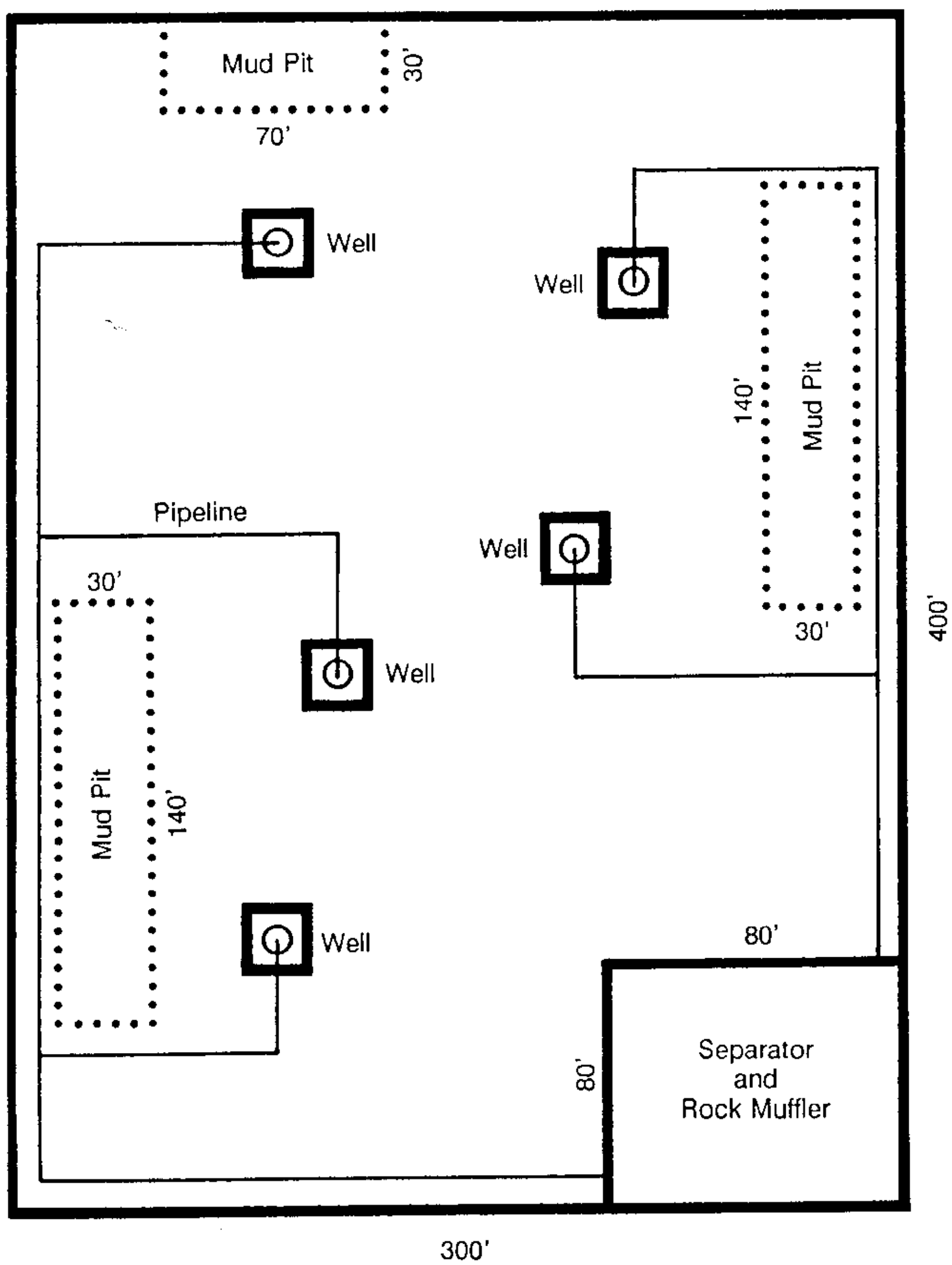


Figure 3-5. Proposed Puna Geothermal Venture Project Wellpad Layout

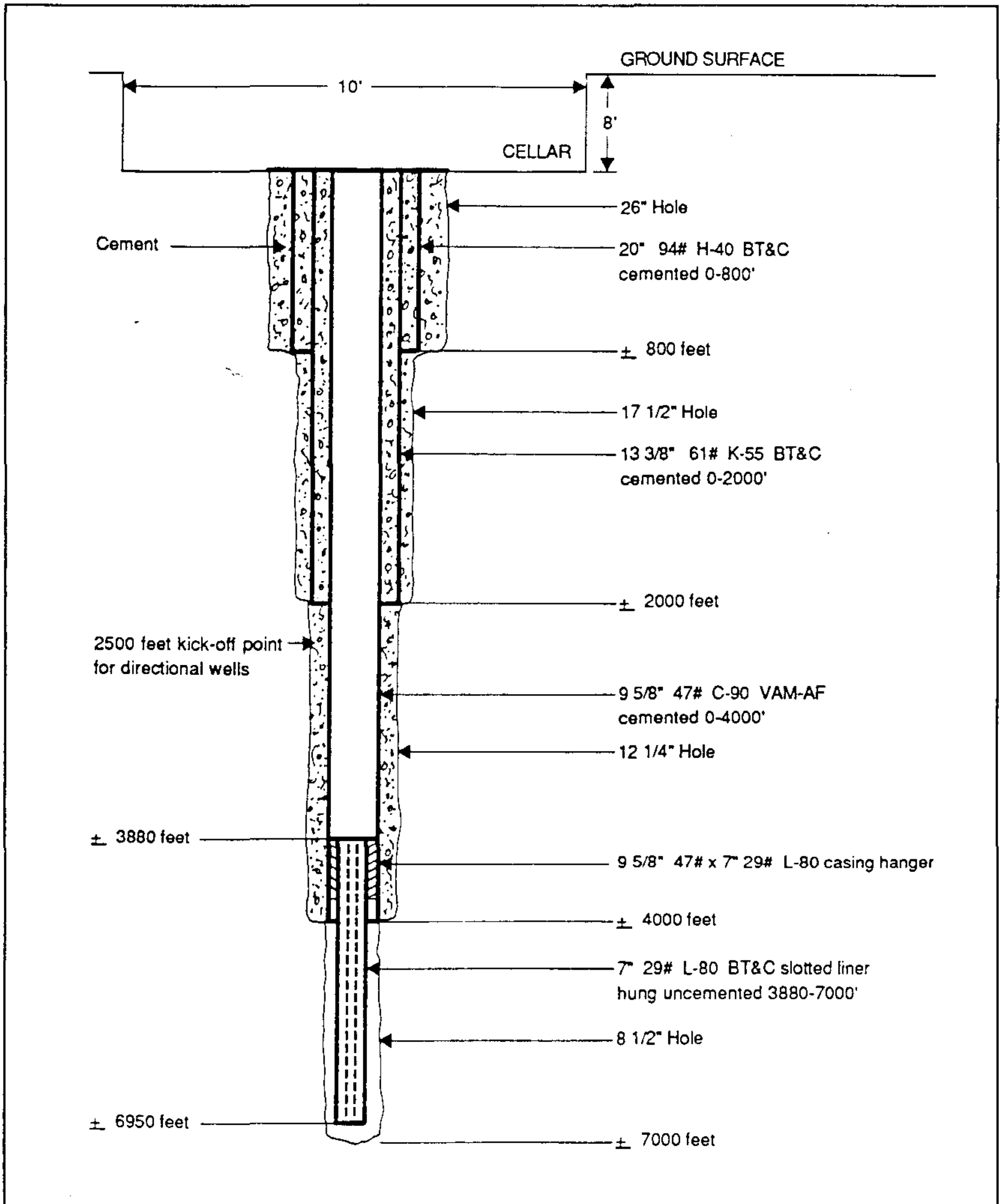


Figure 3-6. Typical Production Well Design

temporarily store drilling wastes, which typically consist of rock cuttings, waste drilling mud, cement particles, lost-circulation material and other drilling mud additives, and other waste drilling liquids.

Once drilling and initial testing of the wells on a wellpad is complete, the drilling rig will be removed and only the rock muffler, a brine/steam separator, and associated piping will remain on the pad. However, the wellpad area must be maintained to allow the return of the drilling rig should any of the wells need to be worked over or new wells drilled from the wellpad.

The existing site access road to the project area is from Pahoa-Pohoiki Road. A new access road is planned from Highway 132, and the existing road will not be used in most instances. To mitigate potential traffic congestion and accidents relating to traffic on Highway 132, a right-hand turn lane will be constructed for vehicles turning into the site off Highway 132. The locations of both of the roads are depicted in the site plan (Figure 2-2). The main access road will allow two-way traffic and will meet local standards for its expected use. The single-lane interior service roads will be about 15 feet wide, surfaced with cinders, and built to accommodate the large trucks used to bring the drilling and testing equipment to the wellpads.

3.2.1.3. Well Drilling

Figure 3-7 shows how the equipment required to drill the geothermal resource wells might appear during drilling operations. This equipment consists of the mast or derrick, pipe racks and drill pipe, mud mixing tanks, mud pumps and air

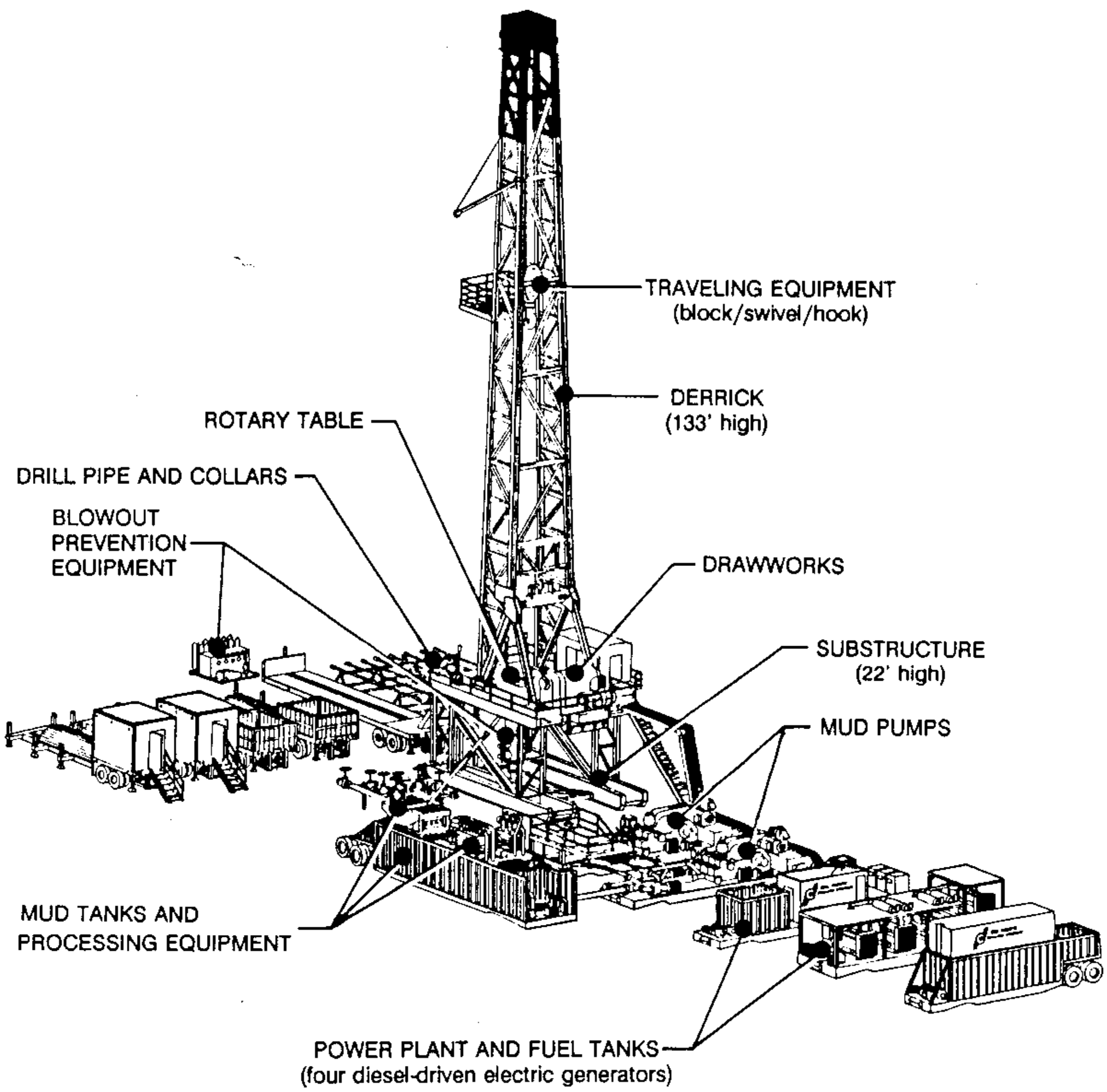


Figure 3-7. View of a Typical Geothermal Well Drilling Operation

compressors, diesel engines, blowout prevention equipment, a muffler or separator for well testing, fuel and drilling water storage water tanks, hydrogen sulfide abatement equipment, and a trailer office, change house, and restrooms for the crews.

The drilling rig will consist of a rig floor with draw works and a rotating table on a steel base structure to raise the rig floor about 20 feet off the ground to allow space for the wellhead and well-control equipment used in drilling. The rig floor is topped by a mast, or derrick, about 130 feet high. The entire rig will be powered by electricity generated by onsite diesel engines. A tank of approximately 11,000 gallons will store the No. 2 diesel fuel oil.

Drilling operations will be conducted on a 24-hour a day, 7-day per week basis until each well is completed. During drilling the wellhead is equipped with a set of control valves which collectively compose the blowout prevention equipment (BOPE). The BOPE is capable of closing (shutting) in a well during drilling operations to contain underground fluids inside the well and prevent any uncontrolled release of geothermal fluids at the wellhead. The BOPE is frequently tested to ensure its proper operation in an emergency.

During drilling in the upper part of the hole, the circulation fluid will be drilling mud, a mixture predominantly of bentonite clay and water, with other, mostly inert, nontoxic additives included in small amounts. See Figure 3-8 for the basic elements of a rotary drilling rig of the type that will be used by the PGV Project. During the final phases of drilling in the production zone, aerated water or aerated mud may be used instead of drilling muds. Drilling muds are typically used in those

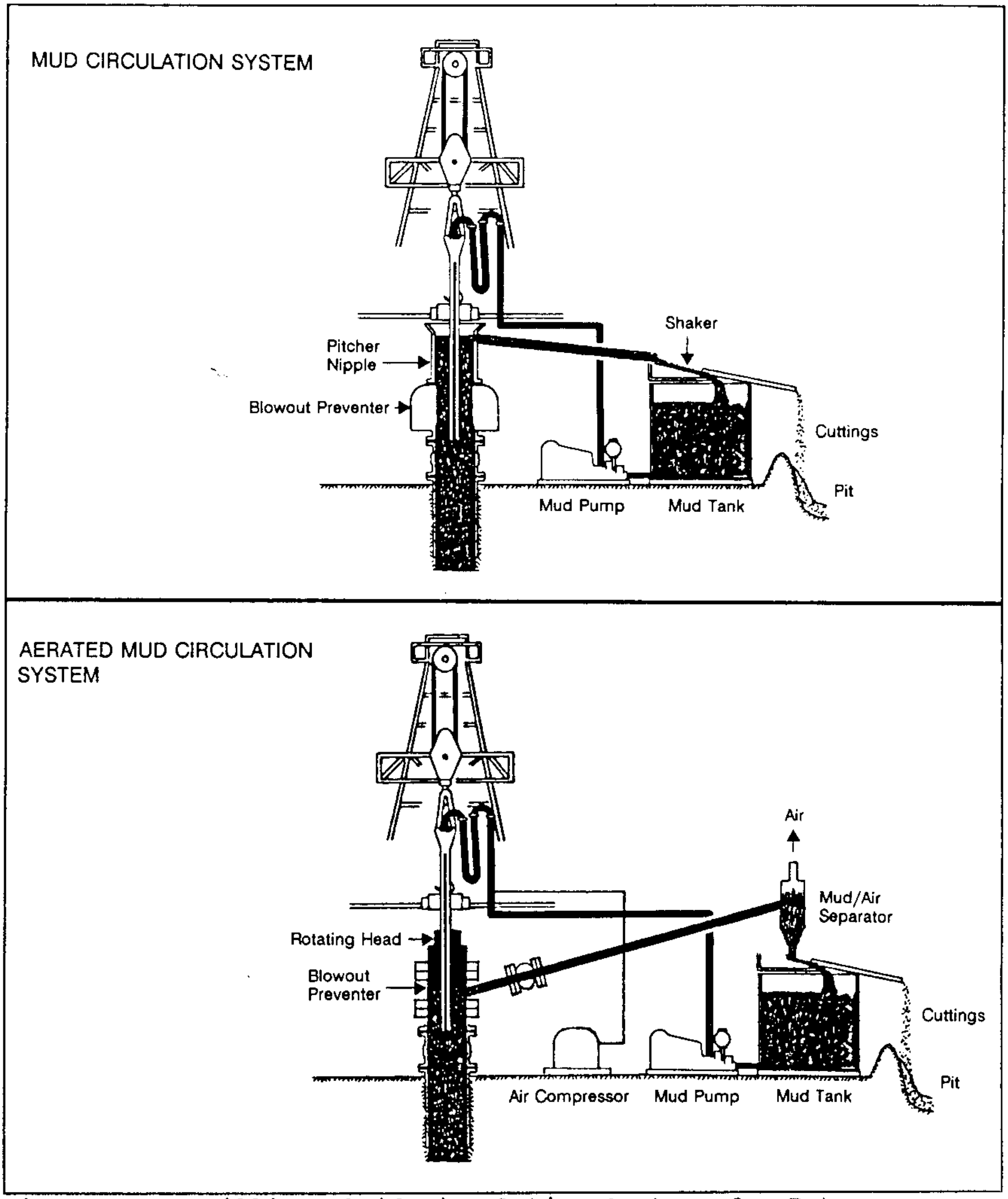


Figure 3-8. Drilling Fluid Circulation System of a Rotary Drilling Rig

portions of the well where water is expected, whereas the reservoir intervals of wells in geothermal fields containing high percentages of steam are preferably drilled with air or aerated water. Drilling typically requires about 30,000 gallons of water per day for the preparation of new drilling fluid, washing of the rig, and other uses.

While drilling with aerated water or aerated mud, which should last no more than about 10 days, pressure of the liquid column of the drilling fluid is greater than the pressure in the reservoir and normally there will be no emission of steam and noncondensables. Occasionally, (about two to six times during the aerated water or mud drilling period) when the pressure of the reservoir overcomes the pressure of the drilling fluid, some steam with noncondensable gases may enter the wellbore and be vented to the atmosphere for a brief period of five (5) to ten (10) minutes. At ten minutes of full steam flow through the annulus (5,000 lb), total unabated hourly emissions will be less than 7 lb of H_2S. If a release occurs, the drilling fluid weight will be immediately increased, stopping the steam flow. If the pressure cannot be restored quickly enough, the BOP equipment will be used to control the flow.

All wells will be drilled into the geothermal reservoir, which starts at a depth of approximately 4,000 feet below the surface. A series of steel casing pipes of gradually decreasing diameter will be cemented at certain depth intervals in order to: (1) maintain circulation of drilling fluids and to prevent contamination of ground waters; (2) prevent the hole from collapsing; and (3) present a clean surface to geothermal fluids. Wells drilled as production wells will consist of 20-inch, 13-3/8-inch, and 9-5/8-inch diameter casings. The 20-inch diameter casing (known as the surface casing) provides hole stability and reduces the loss of drilling mud into fractures near the surface. The 13-/8-inch diameter casing (known as the intermediate casing) will extend from the surface down into the caprock (at approximately 2,000 feet), and 9-5/8-inch casing (known as the production casing) will extend from the surface to about 4,000 feet.

Prior to inserting each string of casing into the hole, the hole is thoroughly flushed and cleaned by circulating fluids. Once this is done, the casing is gradually lowered in the hole and cemented in place. A 7-inch perforated liner will be installed from the bottom of the 9-5/8-inch casing to the bottom of the well at approximately 7,000 feet. This slotted casing helps to maintain well integrity, but is not cemented in place to allow for production of the geothermal fluids into the well to be brought to the surface. All casings will be steel, joined with premium threaded couplings. Figure 3-6 is a diagram of a typical production well, and Appendix B is a drilling and completion program for a typical production well. Average drilling time for the wells will be approximately 45 days.

Directional drilling will need to be used during drilling operations to change or control the direction the drilling is proceeding. This expensive procedure is necessary because more than one well is to be drilled from each wellpad, and the bottom-hole location of each well must be far enough away from each of the other well production zones to avoid unwanted interference between wells. Directionally drilled wells are first drilled vertically to a selected depth and are then gradually deviated in specific directions using down-hole directional drilling equipment.

The following mitigation measures will be taken to ensure the integrity of the geothermal wells and to prevent blowouts:

- Use blowout prevention equipment that can rapidly choke off the flow of fluids from the well during drilling;

- Use conservative safety factors in designing wells and wellhead equipment;

- Install two strings of steel casing cemented in place from the surface into the reservoir caprock;

- Use premium grade casing materials and connections to strengthen the wellbore;

- Specify cement mixtures with high strength and insulating properties;

- Follow correct procedures during cementing of well casing;

- Inspect and test the wellhead equipment regularly; and

- Periodically survey the casing to inspect its condition;

3.2.1.4. Well Cleanout and Testing

Each production well will need to be cleaned out after drilling to ensure maximum well productivity. During initial clean out, each well will be vented vertically to remove dust and drilling debris. PGV has found from past experience from drilling at Puna that vertical venting is necessary for effective cleanout.

Diverting the flow from the wells to a separator or a rock muffler during cleanout would cause large and small particles and mud to accumulate in the equipment and interfere with the flow testing. An analysis of BACT for wellfield emissions was conducted for the previously proposed project, and this analysis confirmed that the application of chemical treatment during well cleanout was impractical, ineffective, and likely to produce adverse environmental consequences. Thus, BACT for well venting consists of limiting the duration of the event and scheduling venting for periods with wind speeds ≥ 4 m/s, meteorological conditions which can be expected to prevent the venting emissions from exceeding the proposed H_2S ambient air quality standard (see Section 3.9).

During this venting, which may last a total of approximately four hours, the H_2S emissions will be unabated. To minimize the amount of H_2S released to the atmosphere during well venting, PGV will implement a program to clean out wells thoroughly prior to ceasing drilling operations by circulating fluids for a longer period of time. PGV will provide proper notification of well venting as required.

Table 3-4 shows the anticipated concentration of H_2S and the other noncondensable gases which will be produced from the Puna geothermal reservoir.

After initial cleanout, the wells will be flow tested to determine the quality, flow, composition and pressure of the fluid and the capacity of the reservoir feeding the well. Each well is anticipated to have a flow rate of between 55,000 and 90,000 lb/hr of steam; 14,000 to 22,000 lb/hr brine; and 50 to 120 lb/hr H_2S. Table 3-5 shows the chemical composition of the

Table 3-4. Composite Noncondensable Gas Composition

Element	Observed Content in Steam[a] (ppmw)	Design Composition (ppmw)
CO_2	250 - 1,042	600
H_2S	800 - 1,300	1,300
NH_3[b]		-
Ar	6 - 13	-
N_2	10 - 700	50
CH_4[c]		-
He	<0.009	-
H_2	11 - 1,412	20
Total NCG	1,500 - 2,200	1,970

Composite data from three wells on the PGV site (KS-1, KS-1A, and KS-2) and the HGP-A well

(a)Wellhead pressure = 155 psig;
Wellhead temperature = 368°F
(b)Below detection limit (<1.5 ppm NH_3 in KS-1A)
(c)Below detection limit (<0.2 ppm CH_4 in KS-1A)

geothermal fluid (brine and steam) anticipated to be produced from the Puna geothermal reservoir. Connections for a portable H_2S chemical abatement unit (consisting of NaOH tanks, injection pumps and piping) will be provided in the steamline from the separator to the rock muffler to be used to abate H_2S emissions during well testing. The NaOH will be injected into the steam stream downstream of the separators.

Initially, well testing may require up to 20 days per well; however, testing durations are anticipated to decrease to 10 days or less as more wells are added and reservoir experience

Table 3-5. Composite Geothermal Fluid Chemical Composition

Element	Brine[a] (ppmw)	Steam Condensate[a] (ppmw)
Na	600 - 10,000	0.17
K	123 - 2,700	0.1
Ca	40 - 920	0.1
Mg	1 - 2	<0.1
Fe	<1 - 8.4	0.05
Mn	<1 - 8.5	-
B	4 - 11	<0.5
Br	40 - 80	-
I	<20	-
F	0.2 - 0.9	-
Li	1 - 9	<0.01
Cl	925 - 21,000	<2
NH	<0.01 - 0.10	0.12
SO_3[b]	9.2 - 24	13
Hg	<0.001 - <0.05	-
As	0.09 - 0.4	<0.01
S[c]	5 - 100	-
Total Alkalinity	≤10	<10
HCO_3	0 - 18	0
CO_3	0	0
SiO_2	420 - 1,500	0.7
TSS	70	-
TDS[d]	2,500 - 35,000	15
pH	≤5 - 5.5	3.5
Conductivity (mhos/cm)	3,100 - 67,000	120
Density	1.03	-

Composite data from three wells on the PGV site (KS-1, KS-1A, and KS-2) and the HGP-A well.

[a]Wellhead pressure = 155 psig;
Wellhead temperature = 368°F
[b]Concentration high due to oxidation of $S^=$ to SO_4
[c]Concentration low due to oxidation of $S^=$ to SO_4
[d]TDS = Total Dissolved Solids

increases. Wells may be flowed continuously or intermittently during the test period. No more than one well will be tested at any one time at the PGV Project wellfield.

Wells that are reworked after commencing operation may also have to be vented vertically and flow tested. The venting will be performed under the same conditions and with the same precautions as after initial drilling. The duration of the flow testing may be less than 10 days, and the steam and gases will either be released through the rock muffler at the wellpad or the flow will be directed through the pipelines to the power plant. In either case, the flow will initially pass through a separator. If the testing is through the rock muffler, the portable abatement unit will be used to inject NaOH into the steamline from the wellhead to the rock muffler such that H_2S emissions are abated by 95 percent. If the flow is directed to the power plant, there will be no emissions due to flow testing of the reworked well.

3.2.1.5.Wellpad Equipment

Each wellpad will contain a wellhead piping subsystem. This system is shown in Figure 3-9. The subsystem begins downstream of the master shutoff valves at each wellhead and includes production, throttling, and isolation valves and instrumentation required for monitoring and control of each well. A rock catcher(rock particle separator) will be installed immediately downstream of each wellhead.

Flash separators, approximately 6 feet in diameter and 12 feet high, will be located in the wellfield. The separators will partition the two-phase flow to steam (approximately 80 percent) and brine (approximately 20 percent). The separators will operate at a pressure of approximately 200 psig. All wells will be equipped with temperature and pressure gauges. Flow from the wells will be measured, and operation of the flow control valves will be manual.

3.2.1.6. Wellfield Gathering Systems

Pipeline systems will collect each of the produced fluids and transport them to the power plant site. Up to three gathering systems will be required: steam, steam pipeline condensate and brine. Figure 3-10 is a process flow diagram of the gathering systems. Each gathering system will be independent of the other systems, interconnecting only at the points where two streams are present; for example, wellfield separators (steam and brine).

All pressure piping will be designed in accordance with the applicable American National Standards Institute (ANSI) codes and in conformance with Hawaii State codes. The piping systems are engineered for the stresses induced by thermal, pressure, dead, and seismic loads, taking into account all planned system operating conditions. Sufficient horizontal and vertical flexibility will be incorporated in the design to withstand ground movements in accordance with the Uniform Building Code (UBC) construction requirements for Seismic Zone 4. Seismic Zone 4 requirements will be incorporated in the design of the PGV Project as an extra safety precaution even though the Island of Hawaii is designated as an area requiring compliance only with the less stringent Seismic Zone 3 standards.

The external surfaces of the pipelines will be covered with insulation and painted in order to blend with the background

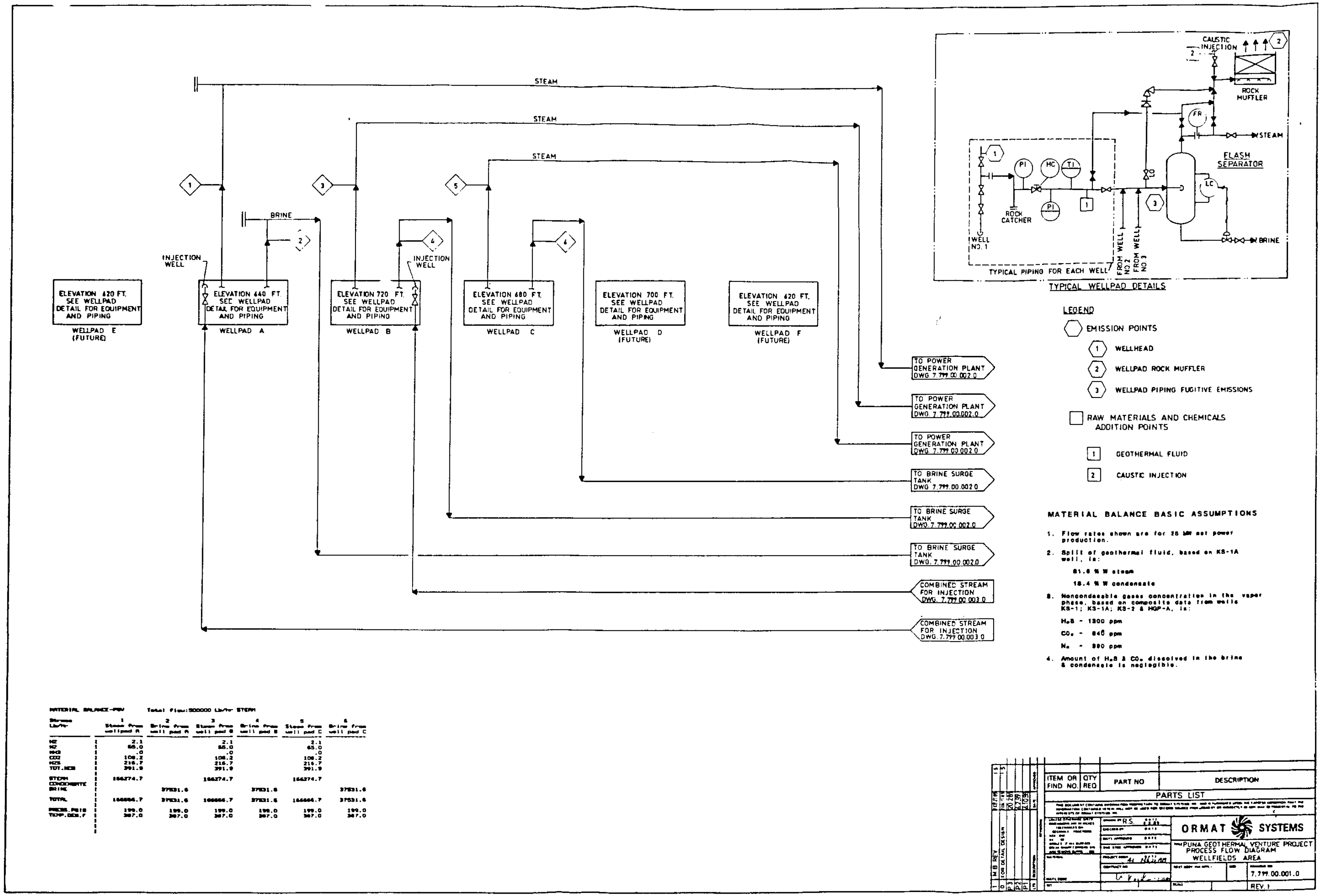
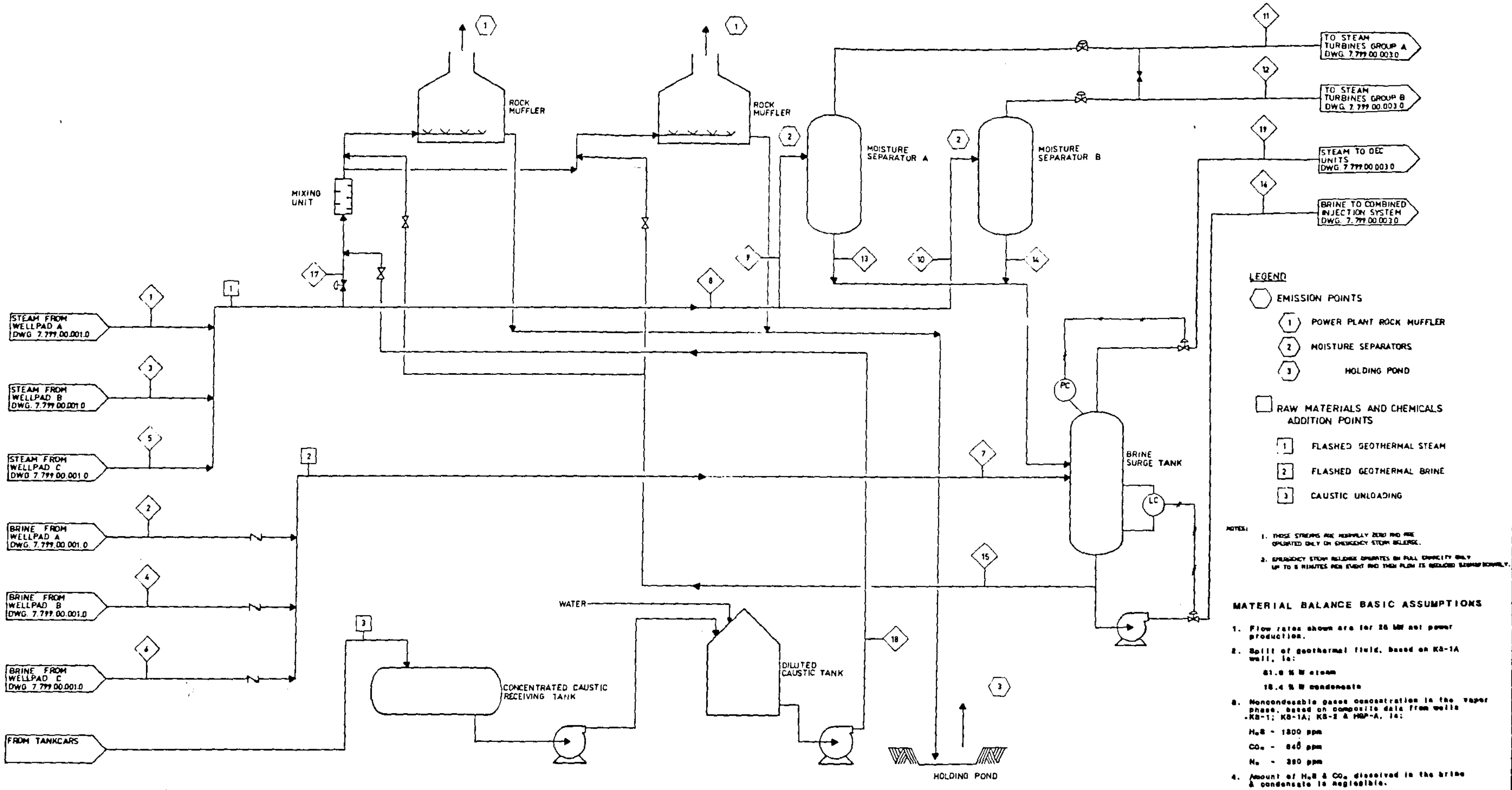


Figure 3-9

Figure 3-9. Wellfield Process Flow Diagram (Dwg. No. 7.799.00.001.0)



MATERIAL BALANCE-PBW Total flow:500000 Lb/hr STEAM

Stream Lb/Hr	1 Steam from wellpad A	2 Brine from well pad A	3 Steam from well pad B	4 Brine from well pad B	5 Steam from well pad C	6 Brine from well pad C	7 Combined brine	8 Combined steam	9 Steam to sep.A	10 Steam to sep.B
H2	2.1		2.1		2.1			6.2	3.2	3.2
N2	65.0		65.0		65.0			195.0	97.5	97.5
NH3	.0		.0		.0			0.1	.0	.0
CO2	108.2		108.2		108.2			324.4	162.2	162.2
H2S	216.7		216.7		216.7			650.0	325.0	325.0
TOT.NCG	391.9		391.9		391.9			1175.7	587.8	587.8
STEAM	166274.7		166274.7		166274.7		1122.1	497329.6	248664.8	248664.8
CONDENSATE								1494.6	747.3	747.3
BRINE		37531.6		37531.6		37531.6	111472.8			
TOTAL	166666.7	37531.6	166666.7	37531.6	166666.7	37531.6	112594.8	500000.0	250000.0	250000.0
PRESS.PSIG	199.0	199.0	199.0	199.0	199.0	199.0	183.0	191.0	191.0	191.0
TEMP.DEG.F	387.0	387.0	387.0	387.0	387.0	387.0	380.0	384.0	384.0	384.0

Stream Lb/Hr	11 Steam to group A	12 Steam to group B	13 Cond.from sep.A	14 Cond.from sep.B	(1) 15 Brine to muffler	16 Brine to inj.system	(1)(2) 17 Steam rel. to muffler	(1)(2) 18 Diluted caustic	19 St.from brn. surge tank
H2	3.2	3.2					6.2		
N2	97.5	97.5					195.0		
NH3	.0	.0					0.1		
CO2	162.2	162.2					324.4		
H2S	325.0	325.0					650.0		
TOT.NCG	587.8	587.8					1175.7		
STEAM	248664.8	248664.8					497329.6		1930.2
CONDENSATE			747.3	747.3			1494.6		
BRINE					110664.8	112189.2			
TOTAL	249252.7	249252.7	747.3	747.3	110664.8	112189.2	500000.0	26318.0	1930.2
PRESS.PSIG	189.0	189.0	189.0	189.0	177.0	200.0	191.0	196.0	177.0
TEMP.DEG.F	383.0	383.0	383.0	383.0	378.0	378.0	384.0	77.0	378.0

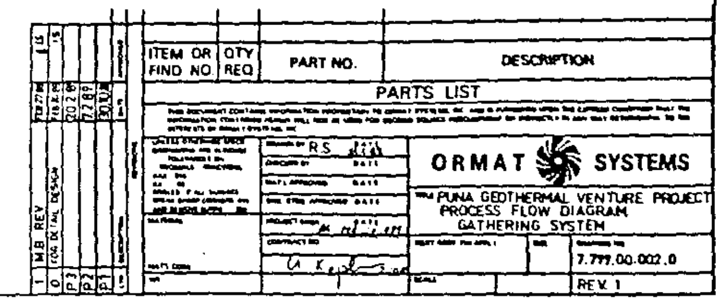


Figure 3-10

Figure 3-10. Gathering System Process Flow Diagram (Dwg. No. 7.799.00.002.0) vegetation and/or volcanic rock and reduce visual impacts, consistent with safety concerns.

Approximately 3,000 feet of pipeline corridor will be needed to connect the six proposed wellpads to the power plant site. The pipelines will generally follow road alignments, wherever possible, to minimize the ground disturbance during installation and maintenance. This is also generally the shortest route from the source to the power plant, which minimizes the heat and frictional losses during transit. However, the pipeline layout may also be influenced by the terrain and the reduction of visual impacts. With a 10-foot wide corridor, ground disturbance for the 3,000 feet of pipelines will be less than 0.7 acres.

3.2.1.6.1.Steam Gathering System

Each steam/brine separator will discharge steam at approximately 200 psig into the steam gathering system. The steam gathering system will then transport the steam to the power plant. The steam gathering system starts out as a single line from each wellpad and which increases in diameter as the steam from other wellpads is connected together. Pipeline diameters will be 12 to 24 inches, depending upon both the amount of steam and the distance that the steam must be transported.

In addition to the pipes and valves involved in the system, the steam gathering system will include moisture separators at the power plant. These separators will remove any entrained water from the steam before entering the steam turbines. (Any water droplets carried into the turbines can cause increased wear on, or damage to, the turbine blades.)

The steam gathering system pipelines will be constructed of carbon steel. Allowances will be made for corrosion and other forms of long-term degradation of the carbon steel pipes. The pipelines will be insulated to conserve as much heat as possible since heat loss leads to condensation of part of the steam and reduces thermal energy and power production.
Steam gathering system pipelines will typically be supported from 2 to 4 feet above the ground. Actual heights will be determined by the terrain and other pipeline design considerations. Steel pillars with concrete foundations will support the pipelines at appropriate distances to prevent sagging. Thermal expansion of the pipe requires that expansion loops be used to prevent damage to the pipes. These loops will be kept horizontal as much as possible, but some vertical loops will be used, such as at road crossings.

Prior to start-up of the plant, the steam gathering system must be cleaned out to prevent dirt and debris from entering the power plant equipment. Cleanout is accomplished by passing the steam from one or more wells through the pipeline and venting it unabated directly to the atmosphere. As with initial cleanout of the wells, it is not practical or desireable to use chemical abatement during pipeline cleanouts, and therefore, pipeline cleanouts will be scheduled during periods when wind speed ≥ 4 m/s, conditions which will provide for maintenance of the H_2S ambient air quality standard. Cleanout will also be scheduled so that it will not coincide with well venting, flow testing, or drilling with aerated water or mud.

3.2.1.6.2.Steam Pipeline Condensate Gathering System

Depending on terrain and distance, a steam pipeline condensate gathering system may be needed to collect steam that condenses in the steam gathering pipelines. If a steam condensate pipeline is installed, drains at the low points of the steam gathering line would allow the condensate from the steam pipelines to enter the condensate gathering system.

The steam condensate gathering system pipelines, if installed, would also be constructed of carbon steel but would be much smaller in diameter (probably 2 inches) than the steam gathering system pipelines. Allowances would also be made for corrosion and other forms of long-term degradation of the pipes.

The steam condensate pipeline would transfer the collected condensate under pressure to a steam line at the outlet of the steam turbines. In general, the condensate gathering system, if necessary, would parallel the steam gathering system.

3.2.1.6.3.Brine Gathering System

The brine gathering system will transport the brine under pressure from the wellfield separators to the brine surge tank, located at the power plant site. From there, the brine would flow to the injection wells, where all geothermal fluids produced during operation of the PGV Project wellfield and power plant (geothermal brine, geothermal steam condensate, and geothermal noncondensable gases) will be combined and injected back into the geothermal reservoir. The pipelines used in the brine gathering system will be 4 to 6 inches in diameter, smaller than the steam gathering pipelines.

The brine gathering system will follow the same corridors as the steam gathering system, and will consist of carbon steel pipelines insulated to maintain heat and painted to blend with the vegetation.

3.2.1.7. Geothermal Fluids Injection System

Under normal operating conditions, essentially all geothermal fluids produced during operation of the PGV Project wellfield and power plant (geothermal brine, geothermal steam condensate, and geothermal noncondensable gases) will be injected back into the geothermal reservoir and only negligible fugitive emissions of the geothermal fluids might be expected.

Recombining of all the geothermal components will probably be in the following sequence: first, the condensate will be cooled and combined with the brine; second, the compressed noncondensable gases will be mixed with the combined condensate and brine to produce one geothermal fluid, which will have basically the same composition as the original geothermal fluid.

PGV anticipates that all three geothermal streams will be combined into one (1) stream and injected into one (1) well, but depending upon the chemical behavior of the combined stream, there is a possibility that brine and condensate will be injected in two (2) separate wells. This decision will be made prior to power plant operation.

Wells will likely be drilled specifically for the injection of the geothermal fluids (see Section 3.2.1.1). Alternatively, marginal geothermal production wells, which are production wells producing less-than-desired steam flow or steam fraction and, therefore, are not economical to use in producing electrical energy, may be used as injection wells. Wells drilled specifically for injection would still be drilled into the geothermal reservoir, but would likely be more shallow than wells drilled as geothermal production wells. This would still ensure reliable, safe injection of the geothermal fluids back into the geothermal reservoir, and would possibly reduce the cost of the well through, as shown in Figure 3-11, the elimination of the intermediate string of casing from the well design. In either event, hang-down strings of special or coated solid steel liners would be used to protect the premium casing of each well during its use as an injection well. These removable strings of pipe will be placed inside the larger diameter casing. Up to three injection wells (two operating plus a spare) will be required to inject the maximum anticipated 570,000 lb/hr (1,140 gpm) of produced geothermal fluids (see Section 3.2.2).

The required well drilling and/or conversion permits will be obtained from the Department of Land and Natural Resources (DLNR), as necessary.

To ensure high reliability of the geothermal fluids injection system, each component of the system will be backed by a spare. A spare fluid pump, a spare noncondensable gas compressor, and a spare geothermal injection well will be provided. However, in the unlikely event of an upset in the injection system, an unlined holding pond will be constructed at the power plant site to receive, and temporarily store until it infiltrates, geothermal brine and/or condensate (see also Section 3.2.2.3). Prior to discharge to the holding pond, the brine will pass through the emergency steam facility and a small amount of steam

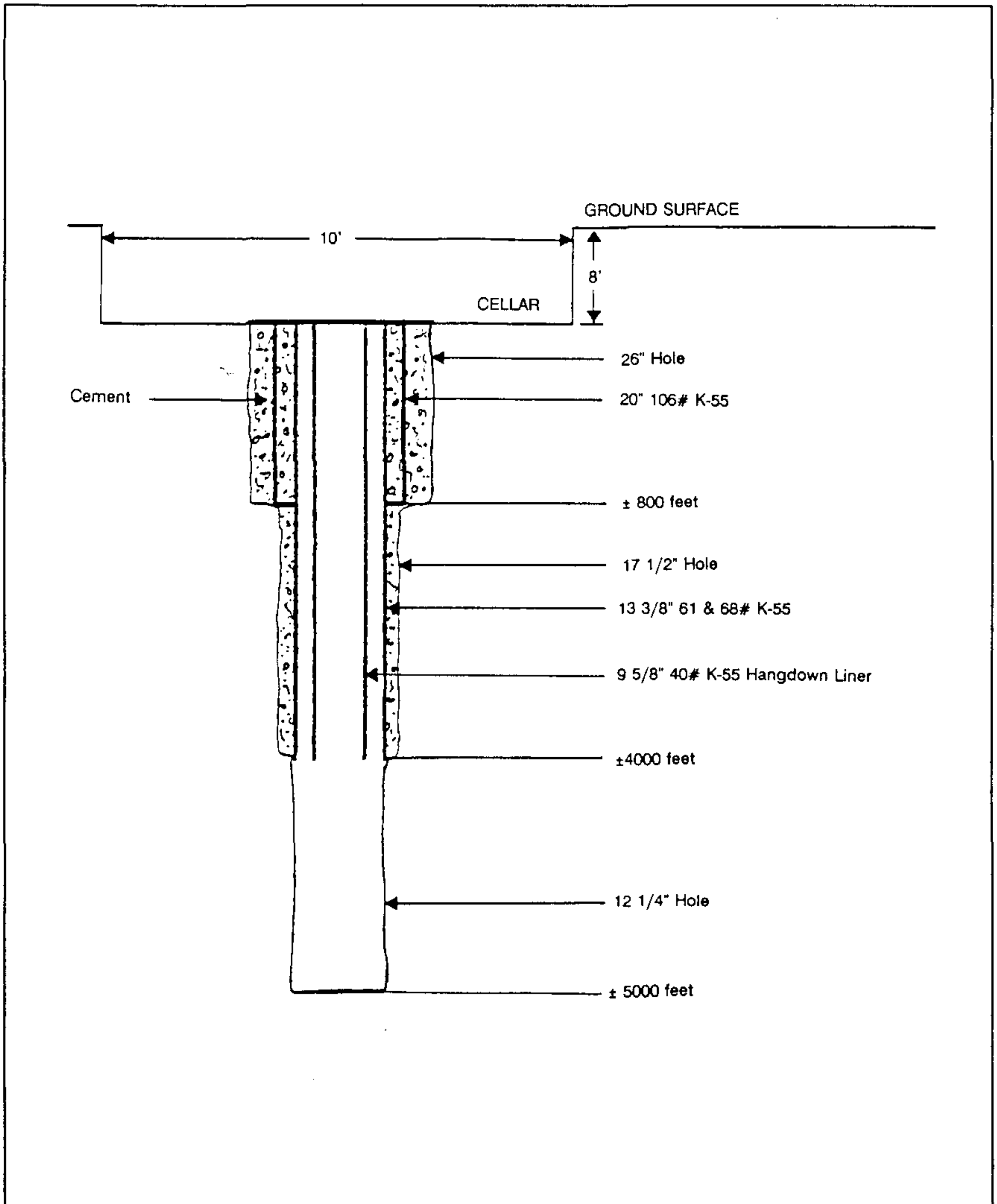


Figure 3-11. Typical Injection Well Design

and H_2S would be released through the rock muffler.

3.2.1.8. Makeup Wells

Over the lifetime of the project, individual geothermal wells may require to be supplemented or replaced because production or injection capability has declined to a point where the well's contribution to the project is minimal. As many as 20 wells may be drilled over the 35-year economic life of the project to maintain full plant output (see Section 3.2.1.1 and Section 3.2.1.3). Wells no longer useful for production or injection may be used for reservoir monitoring or abandoned (see Section 3.2.7).

3.2.2. Power Production Systems

The PGV Project power plant is designed to provide approximately 25 MW of capacity to the HELCO energy grid system. The power plant will be built with a maximum gross capacity of approximately 28.5 MW, with the difference being used by the power plant for internal energy requirements. Actual ambient temperatures and other operating conditions will vary the amount of electricity generated and/or steam required, with more power able to be generated during periods of cooler air temperatures.

The PGV Project power plant will consist of ten modules, each one consisting of a back-pressure steam turbine integrated in series with an air-cooled binary cycle OEC unit, so that steam leaving each steam turbine is utilized in the vaporizer of the companion binary OEC unit. A flow diagram of the power plant, showing a general heat and mass balance, is presented in Figure 3-12. Under normal operating conditions, an estimated 500,000 lb/hr of steam (at 381°F and 184 psig) at the steam turbine inlet will be required to generate the full 25 MW (net) of power, but up to 570,000 lb/hr of steam may be required, depending on actual reservoir conditions encountered (pressure and temperature).

The power generation equipment will occupy the 6-acre power plant site at an elevation of approximately 670 feet AMSL between Wellpads A and B. Figure 3-13 shows the general arrangement of the power plant site. The steam turbine\air-cooled OEC unit modules will be arranged in two parallel banks in the middle of the plant site. All of the auxiliary equipment will be located on the power plant site, except the holding pond and rock mufflers which will be located south of the southeastern corner of the site (see Section 3.2.2.3).

3.2.2.1.Turbine-Generator System

3.2.2.1.1.Steam Turbines

The steam turbines operate by removing the heat energy from the steam and converting it into mechanical work. As the steam expands through each turbine, it increases its velocity. The high-velocity steam pushes against a series of blades in the turbine and rotates the blades. The blades are connected to a central shaft which rotates the generator, which generates the electrical energy.

High-pressure steam at approximately 381°F and 184 psig will be delivered during normal operation and average conditions to the inlet of each steam turbine. After driving the steam turbine, the steam will exit at a pressure still above atmospheric. (Because the steam exits these turbines at a pressure above

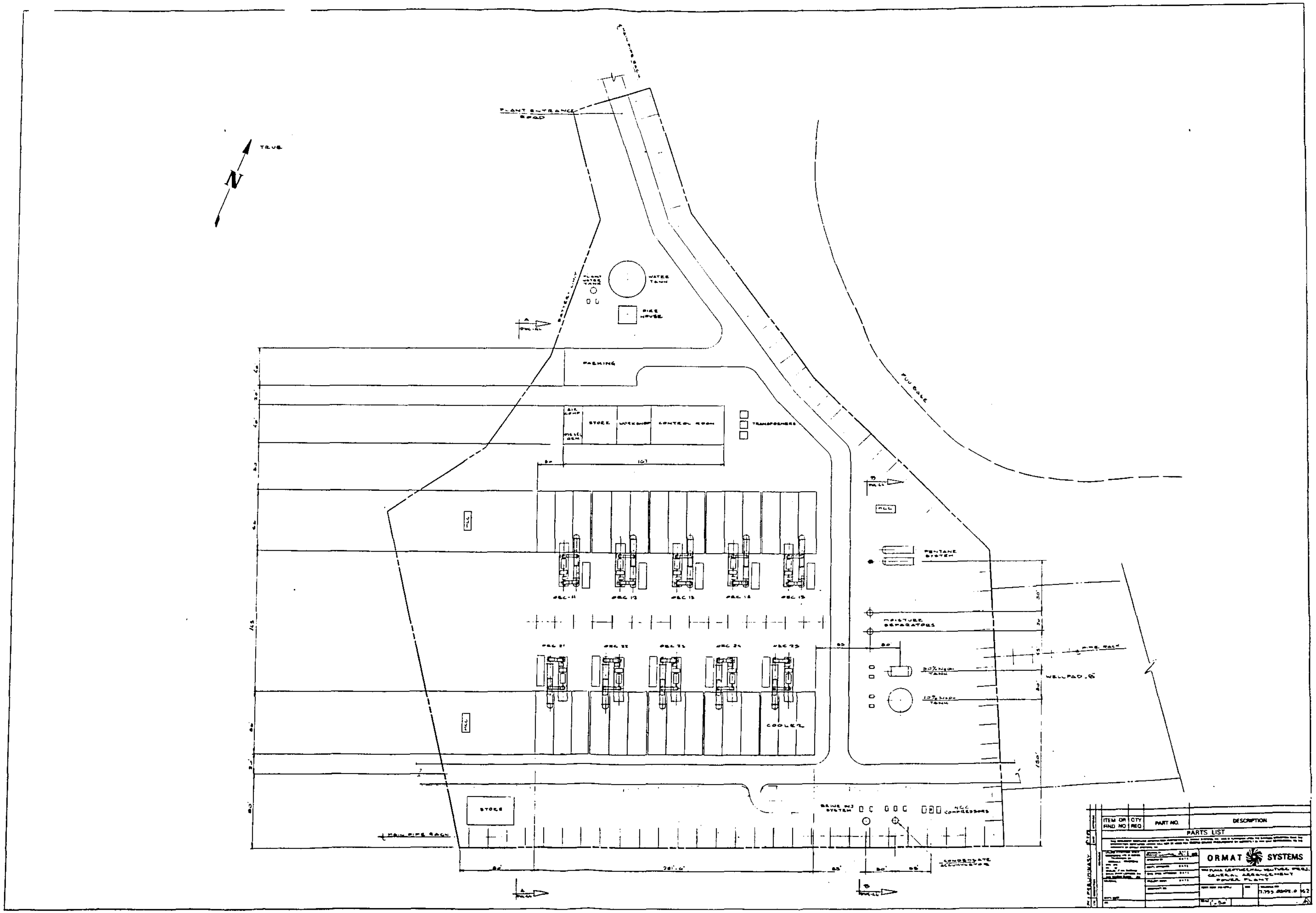
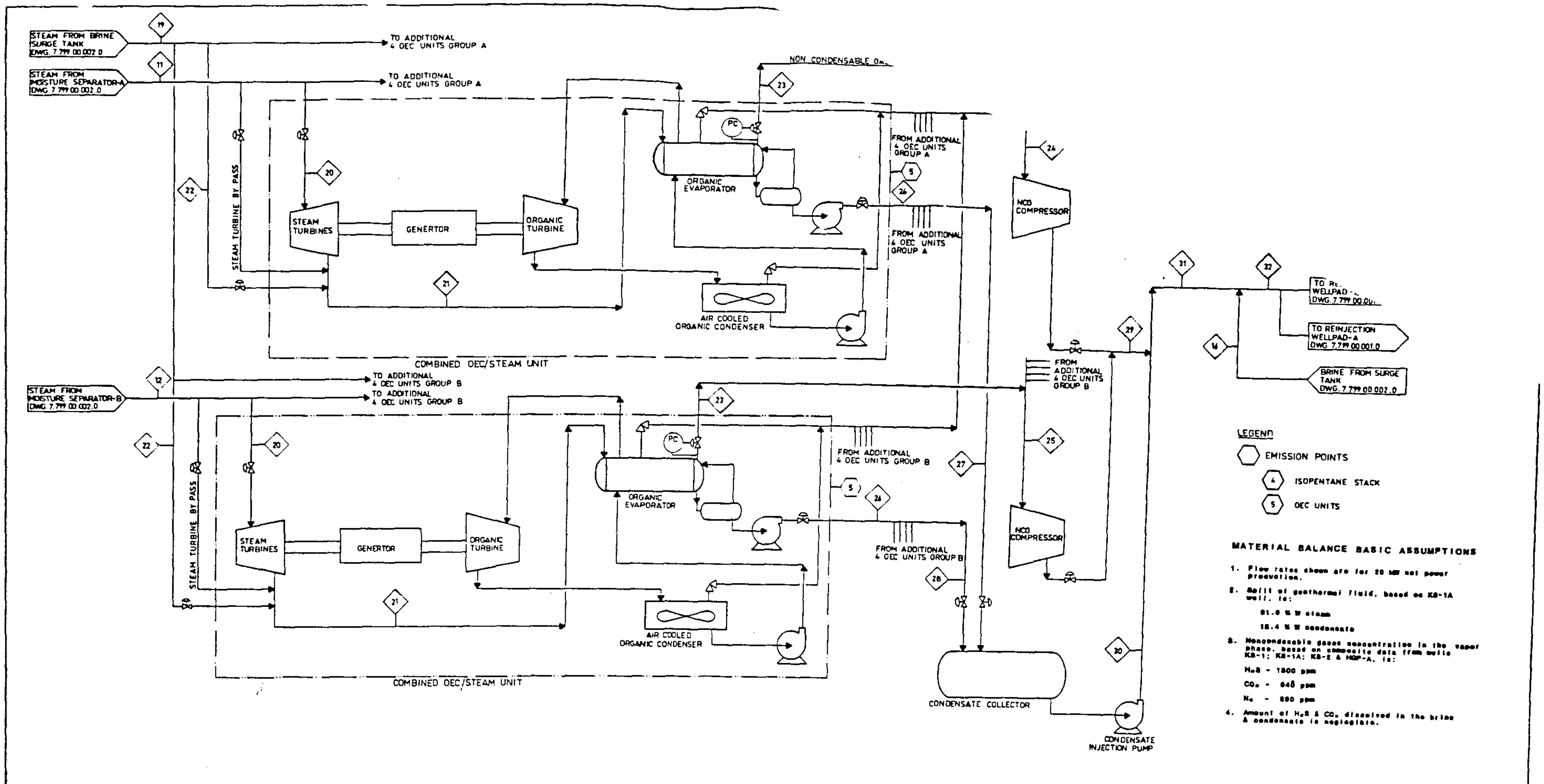


Figure 3-13

Figure 3-13. Power Plant General Arrangement
(Dwg. No. 7.799.00.102.0)



MATERIAL BALANCE - PBV   Total Flow:500000 Lb/hr STEAM

Stream lb/hr	11 Steam to group A	12 Steam to group B	16 Brine to inj.system	20 St.to st. turb.unit	21 Steam to OEC unit	22 Brn.flash to st.turb.unit	23 NCG from OEC unit	24 NCG from OEC group A	25 NCG from OEC group B
AR	3.2	3.2		0.6	0.6		0.6	3.1	3.1
N2	97.6	97.6		19.6	19.5		19.5	97.8	97.8
NH3	.0	.0		.0	.0		.0	.0	.0
CO2	162.2	162.2		32.4	32.4		32.4	162.2	162.2
H2S	325.0	325.0		65.0	65.0		65.0	325.0	325.0
TOT.NCG	587.8	587.8		117.6	117.6		117.6	587.8	587.8
STEAM	248664.8	248664.8		49732.9	49925.9	193.0	176.4	881.8	881.8
CONDENSATE									
BRINE			112159.2						
TOTAL	249252.7	249252.7	112159.2	49850.6	50043.5	193.0	293.9	1469.6	1469.6
PRESS.PSIA	189.0	189.0	200.0	184.0	11.0	177.0	10.0	10.0	10.0
TEMP.DEG.F	383.0	383.0	378.0	381.0	240.0	378.0	238.0	238.0	238.0

Stream lb/hr	26 Cond.from OEC.evap.	27 Cond.from OEC group A	28 Cond.from OEC group B	29 Comp NCG from comp.	30 Comb.cond. from collec	31 Con.& NCG stream	32 Combined inject.str.
AR				6.2		6.2	6.2
N2				195.0		195.0	195.0
NH3				0.1		0.1	0.1
CO2				324.4		324.4	324.4
H2S				650.0		650.0	650.0
TOT.NCG				1175.7		1175.7	1175.7
STEAM				1763.5			
CONDENSATE	49675.3	248301.5	248301.5		496753.1	498526.6	498526.6
BRINE							112159.2
TOTAL	49675.3	248301.5	248301.5	2939.2	496753.1	499702.3	611861.8
PRESS.PSIA	10.0	10.0	10.0	200.0	200.0	200.0	200.0
TEMP.DEG.F	239.0	238.0	238.0	330.0	238.0	240.0	265.0

ITEM OR FIND NO. | QTY REQ | PART NO. | DESCRIPTION

PARTS LIST

ORMAT SYSTEMS

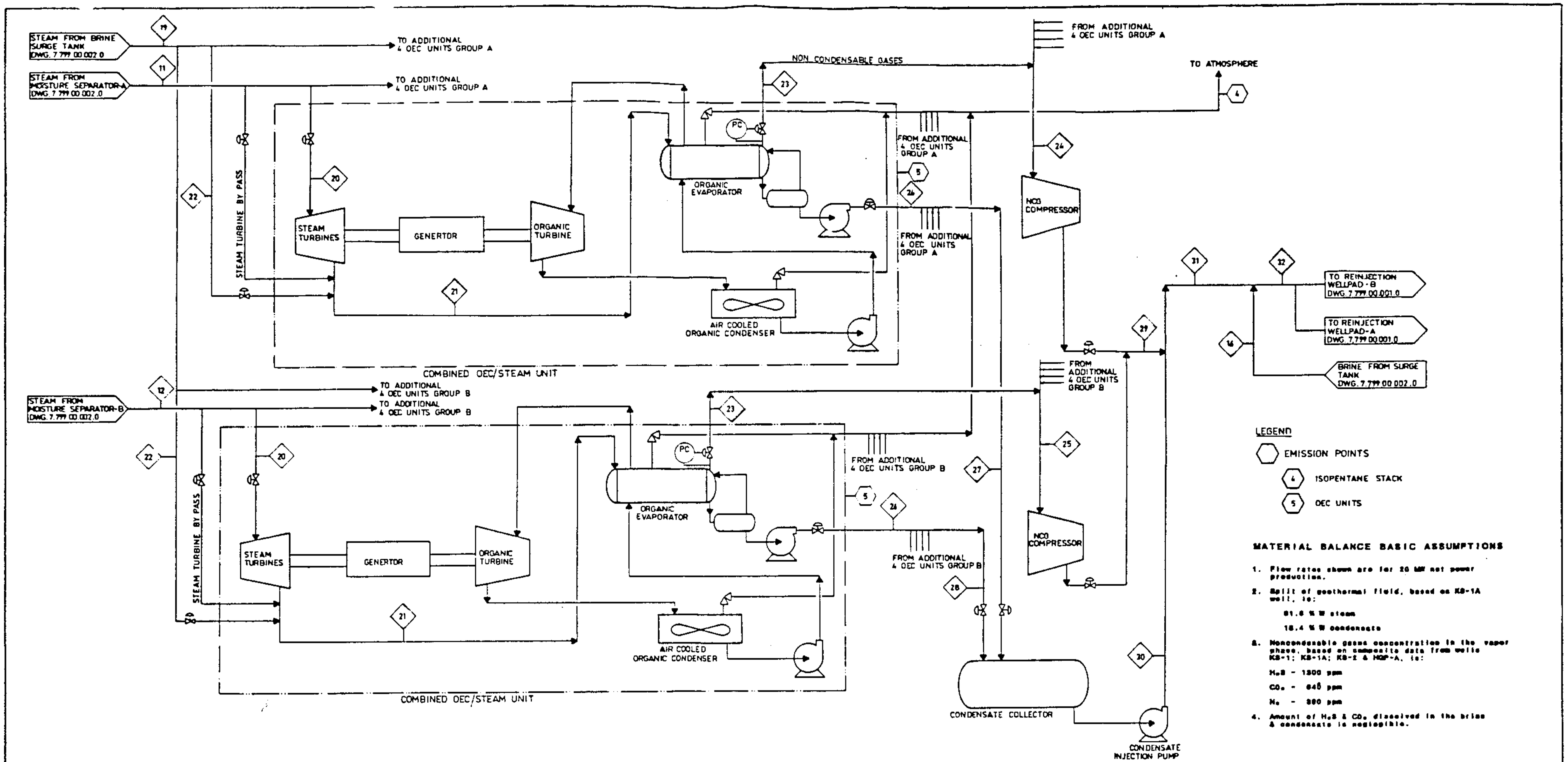
PUNA GEOTHERMAL VENTURE PROJECT
PROCESS FLOW DIAGRAM
POWER GENERATION AREA

7.799.00.003.0

REV 1

Figure 3-12

Figure 3-12. Power Generation Area Process Flow Diagram (Dwg. No. 7.799.00.003.0)



MATERIAL BALANCE BASIC ASSUMPTIONS

1. Flow rates shown are for 25 MW net power production.
2. Split of geothermal field, based on KS-1A well, ie:

   81.6 % W steam

   18.4 % W condensate
3. Noncondensable gases concentration in the vapor phase, based on composite data from wells KS-1; KS-1A; KS-2 & HGP-A, ie:

   H_2S - 1500 ppm

   CO_2 - 640 ppm

   N_2 - 380 ppm
4. Amount of H_2S & CO_2 dissolved in the brine & condensate is negligible.

MATERIAL BALANCE - PGV Total Flow: 500000 Lb/hr STEAM

Stream Lb/hr	11 Steam to group A	12 Steam to group B	16 Brine to inj.system	20 St.to st. turb.unit	21 Steam to OEC unit	22 Brn.flash to st.turb.unit	23 NCG from OEC unit	24 NCG from OEC group A	25 NCG from OEC group B	26 Cond.from OEC.evap.	27 Cond.from OEC group A	28 Cond.from OEC group B	29 Cond.NCG from comp.	30 Comb.cond. from collec.	31 Con.& NCG stream	32 Combined inject.str.
H2	3.2	3.2		0.6	0.6		0.6	3.1	3.1				6.2		6.2	6.2
N2	97.8	97.8		19.5	19.5		19.5	97.8	97.8				195.0		195.0	195.0
NH3	.0	.0		.0	.0		.0	.0	.0				0.1		0.1	0.1
CO2	162.2	162.2		32.4	32.4		32.4	162.2	162.2				324.4		324.4	324.4
H2S	325.0	325.0		65.0	65.0		65.0	325.0	325.0				650.0		650.0	650.0
TOT.NCG	587.8	587.8		117.6	117.6		117.6	587.8	587.8				1175.7		1175.7	1175.7
STEAM	248664.8	248664.8		49732.9	49925.9	193.0	176.4	881.8	881.8				1763.5			
CONDENSATE										49676.3	248381.5	248381.5		496763.1	498526.6	498526.6
BRINE			112159.2													112189.2
TOTAL	249252.7	249252.7	112159.2	49850.6	50043.5	193.0	293.9	1469.6	1469.6	49676.3	248381.5	248381.5	2939.2	496763.1	499702.3	611861.8
PRESS.PSIA	189.0	189.0	200.0	184.0	11.0	177.0	10.0	10.0	10.0	10.0	10.0	10.0	200.0	200.0	200.0	200.0
TEMP.DEG.F	383.0	383.0	378.0	381.0	240.0	378.0	238.0	238.0	238.0	238.0	238.0	238.0	330.0	238.0	240.0	265.0

ITEM OR FIND NO.	QTY REQ	PART NO.	DESCRIPTION

PARTS LIST

ORMAT SYSTEMS

PUNA GEOTHERMAL VENTURE PROJECT
PROCESS FLOW DIAGRAM
POWER GENERATION AREA

7.799.00.003.0

REV 1

Figure 3-12

Figure 3-12. Power Generation Area Process Flow Diagram (Dwg. No. 7.799.00.003.0) atmospheric levels, these turbines are called back-pressure steam turbines.) The low-pressure steam leaving each turbine will be routed to the companion OEC binary unit.

Turbine control and isolation will be provided by control and stop valves in the main steamline, positioned just upstream of the turbines. The turbines will include auxiliary systems (such as lubrication, shaft sealing and cooling) necessary for turbine operation.

3.2.2.1.2.Steam Turbine Bypass

Each steam turbine will be equipped with a bypass system which is designed to direct the high pressure steam around the steam turbine directly to the OEC binary unit.

During turbine upset conditions or start-up, the steam turbine bypass system will route the steam around the effected turbine directly to its corresponding OEC unit. The steam turbine bypass system will allow a generator to operate, in a reduced capacity, while the connected steam turbine is off-line. When a steam turbine bypass system is actuated, the steam turbine bypass valves are opened and the OEC unit, which is capable of operating with high temperature steam, will continue to operate. The steam flow from the wells will be reduced as necessary to accommodate the reduced production capacity of the power plant.

3.2.2.1.3.OEC Binary Units

The low-pressure steam exiting each steam turbine will flow through steam piping to its corresponding 1.2 MW air-cooled OEC binary unit. Each OEC unit is a self-contained generating unit.

Major components of an OEC unit are: a working fluid vaporizer, a turbine, an air-cooled working fluid condenser, and a working fluid recycle pump. The OEC modules will also include automatic and manual control valves, level switches, pressure gauges, pressure controls, internal piping, and power and control boards.

The OEC unit system is based on the Rankine power cycle. The cycle will use isopentane as the working fluid for this project. Isopentane is a colorless hydrocarbon liquid, much like butane or propane (bottled gas), but is much less hazardous because it has a much lower vapor pressure (see Section 3.2.3.5). A schematic flow diagram of the OEC cycle is shown in Figure 3-14. Approximately 298,000 lb/hr of 136°F isopentane working fluid will be vaporized by the heat of the low-pressure geothermal steam flowing through each vaporizer. The resulting 214°F isopentane vapor will expand as it passes through the impulse turbine, which is coupled to a generator that produces 3-phase electrical power. The exhaust vapor is condensed in an air-cooled condenser and recycled to the vaporizer by the working fluid recycle pump. The condensed steam from the vaporizer will be mixed with the brine and the noncondensable gases and then injected into the geothermal reservoir (see Section 3.2.1.7).

The OEC unit vaporizers will be shell-and-tube type heat exchangers designed and fabricated in accordance with the applicable TEMA-C standards and ASME codes (Unfired Pressure Vessels, Section VII, Div. I). Vaporization of the working fluid will take place in the shell side of the heat exchangers, while the low-pressure geothermal steam will flow inside the tubes to facilitate cleaning of the heat exchangers. A liquid separator installed at the outlet of the vaporizer will prevent liquid isopentane droplets from being entrained in the vapor and

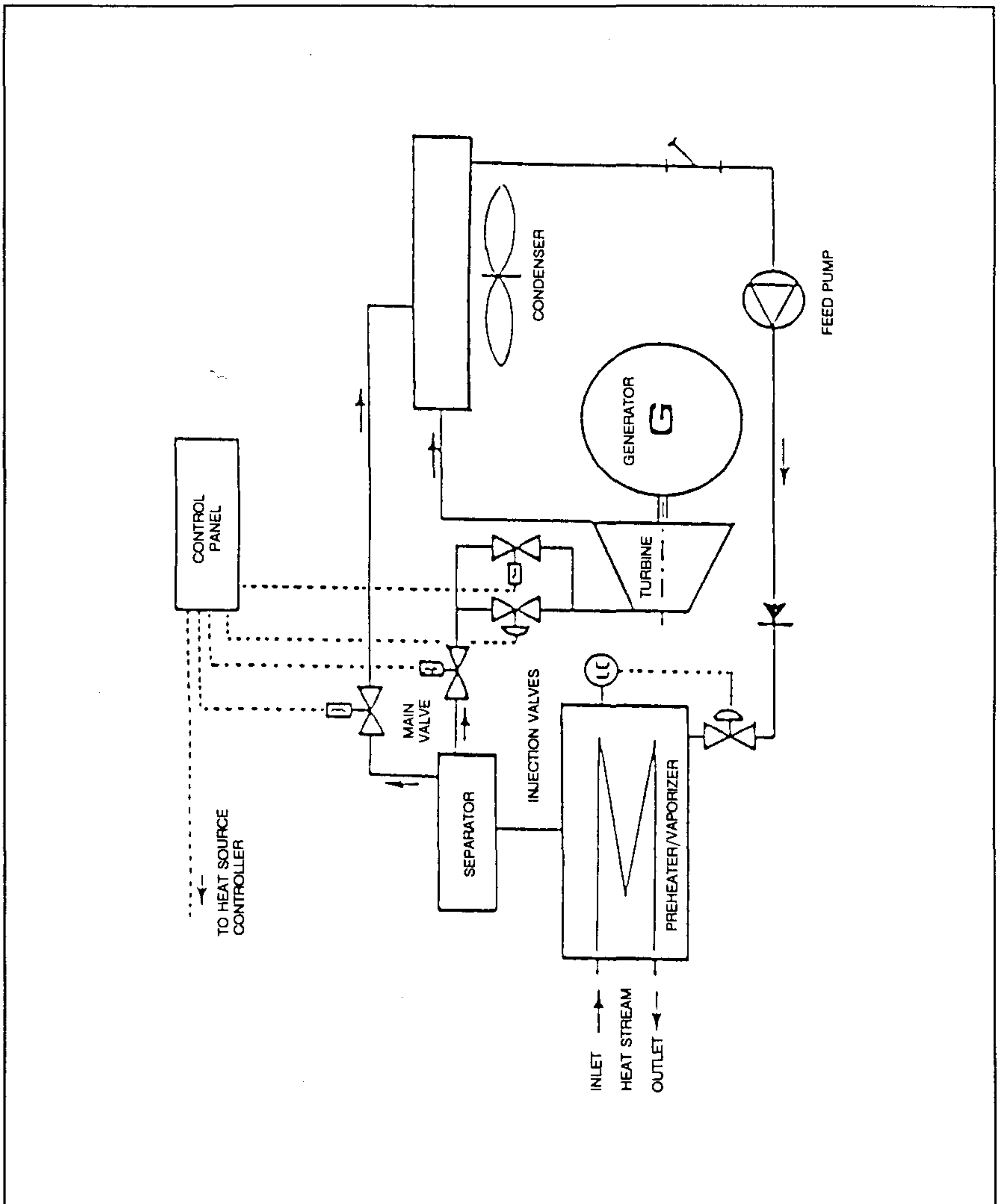


Figure 3-14. Ormat Energy Converter Unit Schematic Flow Chart

subsequently impinging on the turbine impeller blades. The OEC turbines will have injection nozzles and turbine blades specifically designed to operate with organic vapor. The injection valves will be designed to operate at high efficiencies over a wide range of process conditions.

After passing through the turbine, the vaporized working fluid will be routed to an air cooling unit, the top of which is elevated approximately 24 feet above ground level. Vertically mounted fans will force air across the condenser vapor tubes, removing sufficient heat to condense the working liquid. The condensed isopentane will accumulate at the feed pump suction inlet by gravity flow. The air coolers will be sited adjacent to the OEC unit turbine-generator and vaporizer as shown in Figure 3-13. The propeller fans for each set of air coolers will be driven by electric motors by means of a positive drive belt. Air cooling will completely eliminate the drift, gaseous emissions, water requirements, and liquid blowdown associated with water cooling towers.

The cycle feed pump, controlled by a level control device, will pump the working fluid to the vaporizer. The motor-driven pump is a multi-stage centrifugal pump with mechanical seals and is characterized by overall high efficiency and low net positive suction head.

The OEC units will be equipped with pneumatic valves to regulate the flows of vapor and liquid in the organic fluid cycle. All valves will be designed and constructed in accordance with the ANSI Class 150 or 300, as appropriate. The OEC units will also have an internal bypass to divert the isopentane vapor directly to the air coolers in case of malfunctioning of the turbine or the generator.

Operation of the power plant will result in some fugitive isopentane emissions. Mechanical seals on each OEC unit are designed and manufactured as per API 610 specifications, and fugitive emissions from the mechanical seals on each OEC unit will be only about 60 gallons per year, or less than 0.032 lb/hr. Negligible emissions of isopentane to the atmosphere may occur from other minor system leaks during normal operations. Fugitive isopentane emissions will not exceed 0.4 lb/hr total from all OECs. Maximum isopentane concentrations will not exceed 1000 ppm from any seal, flange, valve or other fugitive emissions point, when measured from a distance of 2 inches (5 cm) from the point.

Upset operational emissions of isopentane to the atmosphere could occur upon activation of any of the isopentane pressure relief valves (of which there are two on each OEC unit) or upon certain other unlikely equipment upsets. However, because each of the OEC units are independent modules, the amount and duration of any such release will be limited. The release point will be from a 32-foot stack at one of the ends of the air cooler for each OEC unit, and dispersion will be enhanced by the action of the air cooler fans.

Should an overpressure situation arise in an OEC unit, an alarm will be activated, and the unit will be shut down automatically. The maximum release from an individual OEC unit is expected to be 2,500 lb, one-third of the contents of an OEC unit. Typically, after only a few seconds, the pressure in the working cycle is expected to drop, and the relief valve will close.

3.2.2.1.4.Generators

Each steam turbine and OEC turbine will be connected to a common 3,600 rpm, 13.8 kV electric generator. The generators convert the mechanical energy of the turbines into 3-phase electrical power. The 13.8 kV generators will be cooled by air. Protective devices will guard against overcurrent, overvoltage, loss of field, and fluctuation in frequency. Dedicated power circuit breakers will serve each generator.

3.2.2.2.Noncondensable Gas Control

Under normal operating conditions, there will be no emissions of H_2S other than negligible fugitive emissions from piping joints, which will be minimized through proper design, ongoing maintenance procedures and monitoring by plant operators. All other noncondensable gases produced at the wells will be injected back into the geothermal reservoir.

Almost all of the noncondensable gases produced from the geothermal reservoir with the geothermal fluids will be partitioned with the steam in the flash separators and will pass through the steam turbines. As the low-pressure steam leaving the steam turbines is condensed in the OEC vaporizers, the noncondensable gases and residual water vapor will remain under low pressure. With the design composition of the noncondensable gases in the Puna Geothermal field, an estimated 650 lb/hr H_2S and 324 lb/hr CO_2 will be passed through the ten (10) OEC unit vaporizers. These gases will be piped from the vaporizers of the OEC units to gas compressors, which will compress the gases prior to injection into the combined steam condensate and brine line and, ultimately, will be injected into the geothermal reservoir (see Section 3.2.1.7).

Dissolving H_2S and/or CO_2 into water is a well-known operation in the field of chemical engineering. The abatement of H_2S and CO_2 emissions by gas injection, as described above, has been demonstrated successful at the Coso geothermal reservoir in California since July, 1987. Gas injection has the advantage of not only controlling H_2S, but also abating other produced noncondensable gases, including the emission of CO_2. (CO_2 is the gas considered most responsible for the "greenhouse effect," the accelerated warming of the earth's atmosphere due to increased absorption of infrared radiation.)

During start-up and extended periods of operation below 50 percent of rated capacity, water may be needed to maintain injection flow and to provide a sufficient quantity of fluid to absorb the noncondensable gases. Maximum requirements are estimated at 500 gallons per minute, which could be supplied by one or two wells developed near the plant site. PGV is still evaluating the need for this supplementary water, which will depend on the final design of the injection system. No additional water will be needed during normal operation.

To ensure high reliability of the geothermal fluids injection system, each major component of the system will be backed by a spare. A spare fluid pump, a spare noncondensable gases compressor, and a spare geothermal injection well will be provided. However, in the unlikely event of an upset in the injection system, the brine will pass through the rock mufflers, where it will be flashed, and then sent to the holding pond. Complete failure of the injection system would cause the entire power plant to go off line, and steam would be released through the steam release facility. Since the brine will be routed through the other rock muffler at atmospheric pressure, the gases released from the brine can be treated, and negligible H_2S emissions are expected from the holding pond.

3.2.2.3.Steam Release Facility

The steam release facility will be used to release steam and treated noncondensable gases to the atmosphere under certain relatively uncommon upset conditions. Under most upset conditions of the power plant generating units, such as a steam turbine trip or OEC unit failure, the steam flow from the wellfield (reduced as necessary) will bypass the effected unit or units and the remainder of the steam turbines and OEC units will continue operating (see Section 3.2.2.1.2). Only if there were a failure of the electrical transmission line(s) out of the power plant (or some incident, such as an electrical outage, occurred that tripped all the steam turbines and the OEC units), or there were a complete upset of the geothermal fluid injection system (which is extremely unlikely, for all the reasons presented in Section 3.2.1.7), or if pressure in the steam lines exceeded design set points (which would release excess steam through safety relief valves) would steam be released through the steam release facility. Over a period of up to four (4) hours, the flow from the geothermal wells would be reduced gradually to about fifty (50) percent, the minimum flow determined appropriate to maintain well temperatures. After reduction, not more than about 285,000 lb/hr steam (fifty (50) percent of full flow) would continue to be released through the steam release facility until the power plant could recommence operations.

The steam release facility will consist principally of two rock mufflers installed near the power plant site. The rock mufflers will be constructed of heat-resistant reinforced concrete or other appropriate material and filled with lava rock. The mufflers are designed to dissipate the steam's acoustic energy, thereby reducing the noise associated with a steam release. Each muffler will be designed to handle 570,000 lb/hr steam, which is 100 percent of the maximum total plant steam flow. (If the valves to the emergency steam release facility failed to operate, the steam would be released through relief valves in the steam gathering lines, which will be set at slightly higher pressure points.)

Prior to entering the steam release facility, the steam will be treated with NaOH and water to remove the majority of the H_2S. The effective reactions are:

$$H_2S + NaOH \leftrightarrow NaHS + H_2O$$
$$H_2S + 2NaOH \leftrightarrow Na_2S + 2H_2O$$

Based upon state-of-the art rock muffler design and current experience, 96 percent removal of the H_2S is anticipated from the NaOH treatment system. After the 50-percent reduction in steam flow, effective H_2S control will be 98 percent. Storage tanks will be provided at the power plant site for the NaOH. Injection pumps will meter the NaOH injected into the steam line.

3.2.2.4. Electrical Systems

The power plant will contain several electrical systems. The major electrical equipment includes the main power, auxiliary, station service, and current and potential transformers;

generator circuit breakers; high-voltage switchgear; load centers; motor control centers; and station batteries.

The power from each 13.8 kV generator will be fed to the 13.8 kV busbars, with a switchgear for each generator. Each 13.8 kV busbar will be connected to a 13.8/69 kV step-up transformer and power will be fed into the HELCO switching and metering yard at a voltage of 69 kV. The 13.8 kV/480 V step down transformers will supply 480 V power for all the power plant internal requirements and for the auxiliary systems.

A 250 kW diesel-generator unit will be installed at the plant site to produce power for essential electrical services at the PGV site under emergency conditions, if needed, as well as to enable cold start-up of one OEC unit without external power. The power that would be generated from the diesel-generator would be sufficient to cold start-up and, at the same time, support one air compressor; the battery chargers; the heating, ventilating, and air conditioning (HVAC) system; control room systems; steam release facility H_2S abatement system; and emergency lighting. The 250 kW standby generator is not expected to operate more than 50 hours a year, based on two 24-hour transmission line outages. This estimate assumes that at least one steam turbine/OEC module will be able to operate under other steam release situations.

3.2.2.5.Control Systems

The control system consists of three control subsystems:

- The wellhead control subsystem;

- The OEC control subsystem; and

- The power plant control subsystem.

3.2.2.5.1.Wellhead Control Subsystem

The wellhead control subsystem includes the individual wellheads, the wellpads, the gathering systems and the emergency steam release facility.

All wellheads will be equipped with temperature and pressure gauges on the well casing below the master valves. Flow from each wellhead will be regulated manually. The steam flow leaving each wellpad will be measured. Control valves at the steam release facility will have air-piston operators that respond automatically to signals from the plant control room or upon sensing over-pressure in the steam pipeline. The H_2S abatement system at the steam release facility will operate automatically when steam is released through the rock mufflers.

3.2.2.5.2.OEC Control Subsystem

The OEC control, housed in an individual OEC control shelter located adjacent to each OEC module, will control both the steam turbines and the OEC units.

A programmable controller will be used to record, process, and signal steam and working fluid pressures, voltage levels, speed, kilowatt output, and current of each OEC unit as well as its steam turbine unit. The programmable controller provides diagnostic as well as control functions and will allow the operator to isolate an individual unit for testing or repairs and then automatically restart it after the failure condition has been rectified.

The individual OEC control shed will also house the high power, high voltage components of the OEC units including the circuit breakers, magnetic contacts, fuses, transformers, power capacitors, metering instruments, overload, short circuit asymmetry, and reverse power protective devices.

3.2.2.5.3. Power Plant Control

The entire power plant is designed with a computerized automatic control system that will require a minimum number of personnel to operate the plant. The plant operators will monitor the plant during operation from the main control room, with regular onsite monitoring of all equipment. Individual and plant-wide control systems will operate automatically to prevent injuries to plant personnel or equipment and to protect public health and safety. Standby equipment will start automatically to avoid tripping a turbine unit during normal operations. Monitoring data will be logged and stored in the programmable controller. Information and control signals from the individual OEC controllers will be recorded and controlled from the main power plant control room.

3.2.2.6. Auxiliary Systems

The primary auxiliary systems will be the compressed air system, HVAC system, service water system, and fire protection system.

3.2.2.6.1. Compressed Air System

Compressed air is required for instrumentation, control, and plant maintenance (service air) requirements. Compressed air at 100 psig is distributed throughout the plant from a central compression system that includes air compressors, desiccant-type dryers, and dry-air storage tanks.

3.2.2.6.2. HVAC Systems

Air conditioning will be provided for the electrical equipment and control room. The system will be designed to prevent heat buildup and maintain a positive pressure in the rooms. The air conditioning will include a sealed refrigeration system and coil, outside air supply duct, and an air distribution fan.

3.2.2.6.3. Fire Protection System

The fire protection system will be designed in accordance with applicable National Fire Protection Association (NFPA) and Hawaii State standards and will include the following:

- Fire protection water supplies, pumps and controllers, yard mains, hydrants, and valves.
- An automatic wet pipe and fusible link sprinkler system or CO_2 or Halon equipment in the control room.
- Automatic fire protection system for electrical systems.
- Portable extinguishers with backup water hoses in the control room.

A water tank will be the primary source of water for fire suppression. The volume of the storage tank will be adequate for storing the quantity required according to local regulations, NFPA standards and insurance company requirements. The 315 hp firewater pumps will be diesel driven. Hose stations will be strategically positioned in the plant.

The control room, motor control center, and electrical equipment rooms will be protected with an automatic fire protection system. CO_2 or Halon fire extinguishing equipment may be used in these areas to prevent water damage. If CO_2 is selected, water hoses would also be installed in the event that the CO_2 fails to extinguish the fire. Portable extinguishers will also be provided in the control room.

3.2.2.6.4. Service and Supplemental Water

Service water will be used for general purpose cleaning and maintenance of the power plant. A 2,000-gallon (approximately) tank will provide the service water for the facility.

Supplemental water may need to be added to the fluid injection system during periods of operation at low-load or during start-up to ensure maintenance of the water column in the injection system, which is necessary for proper operation of the gas control system. Up to 500 gpm will be obtained from one or two onsite wells, drawing water from the geothermally influenced groundwater below 600 feet.

3.2.3. Power Plant Structures and Facilities

3.2.3.1. Buildings

There will be one main building for the central control room, offices, warehouse, workshop, air compression system and the emergency generator (see Figure 3-13 and Figure 3-15). The structural steel side walls and roof framing are covered with metal siding and roofing. The structure will be painted to blend with the surrounding area. In addition, there will be ten shelters for the OEC units and another storage shed for the heavy equipment.

3.2.3.2. Structural Design

All major structures are of steel frame construction. The structures and major equipment rest on footings. Minor equipment is placed on slab floors or mounted on walls. Anchors will secure all equipment to foundations, mounting pads, or surfaces. All major structures, foundations, and footings will be designed to support all applicable loads and will be designed for Seismic Zone 4 requirements.

3.2.3.3. Foundation Design

The steam turbines reinforced-concrete, OEC units, and air coolers will each sit on reinforced-concrete foundations. The outdoor electrical transformers will be mounted on concrete foundations.

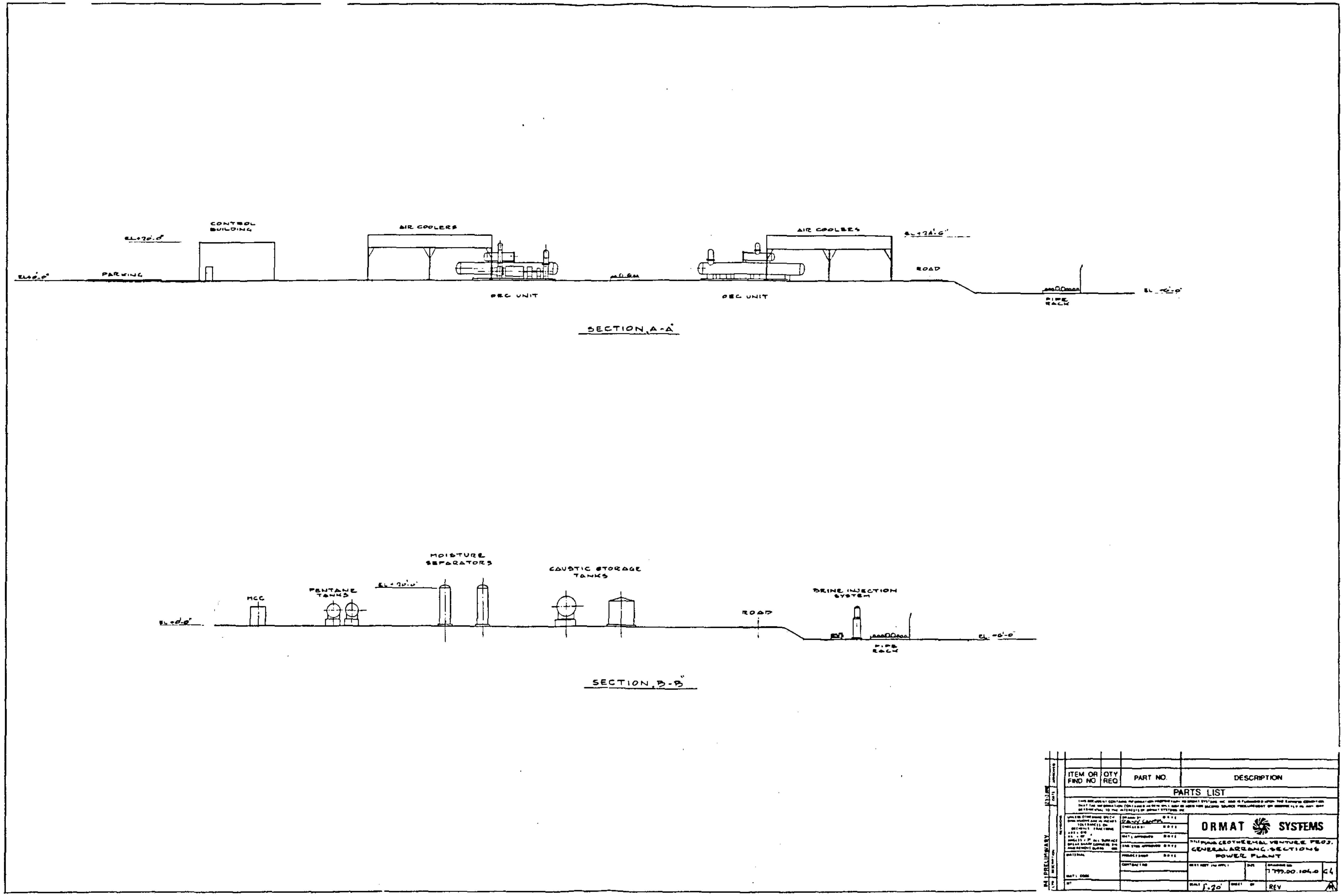


Figure 3-15

Figure 3-15. Preliminary Elevation Drawings of the Power Plant (Dwg. No. 7.799.00.104.0)

3.2.3.4.Site Drainage Facilities

The high porosity of the volcanic soils and rock in the site area results in rapid downward percolation of rainwater. Concrete pads and berms are provided to contain possible spills in areas where chemicals are handled. Catch basins, culverts, ditches, and berms are provided for drainage control where necessary.

3.2.3.5.Chemical Storage Facilities

The only hazardous chemicals used in significant quantities will be isopentane and caustic soda (NaOH).

Isopentane is a colorless liquid that vaporizes at 82°F. It is not toxic or corrosive, but is flammable at concentrations between 1.4 percent and 8.0 percent (volume) in air. Isopentane is similar to propane (bottled gas), which is used for heating and cooking in many rural locations, but is much less hazardous than propane because of its higher boiling point and lower vapor pressure.

Each OEC unit will contain approximately 7,500 pounds of isopentane. Additional isopentane, as much as 10,000 pounds, will be stored onsite in two tanks which also have sufficient capacity to receive the entire isopentane contents of an OEC unit. The tanks will have a design temperature of 250°F and design pressure of 150 psig. Working fluid pumps will be used to transfer isopentane to and from the tanks to recharge the systems or remove the isopentane from OEC units requiring maintenance.

To reduce the possibility of isopentane presence in flammable concentrations at ground level due to release from one or more of the safety relief valves located at the OEC heat exchangers, each relief valve is furnished with a pipe, releasing to the atmosphere eight (8) feet above the air coolers, which is the highest point in the plant. This release height is in conformance with API and NFPA safety standards for this gas.

Caustic soda (NaOH) is a corrosive material that is toxic if ingested and can cause skin and eye irritation upon contact. It is soluble in water and used in households as a cleaning agent. NaOH will be delivered to the site as a 50-percent solution and stored in two tanks: one with a 50-percent solution as delivered, and the other with a 10-percent solution, diluted for use in the abatement system.

Secondary containment structures such as dikes or berms will be constructed around the NaOH storage tanks. These tanks will be segregated by distance from any incompatible materials. Applicable federal regulations (e.g. OSHA and EPA) and Hawaii regulations (e.g. DOSH and DOH) will be incorporated into procedures and standard policies of the facility. Applicable Department of Transportation (DOT) regulations (Title 49 CFR, Sections 171-178) will be incorporated into the procedures for delivery of any hazardous materials used on site.

3.2.3.6. Fencing

A six-foot-high chain-link fence will be installed around the power plant site boundary and each of the wellpads. A gate at each entrance to the sites will restrict unauthorized access.

3.2.4. Construction

Site construction presents employment opportunities for skilled and unskilled labor. An average of approximately 23 people will be needed throughout the construction period. Estimated peak construction employment at the site is expected to be 100 persons. Most of the construction work is anticipated to be accomplished by local contractors and the local labor force. Site construction activities (other than geothermal well drilling) will be restricted as much as possible to daylight hours.

A temporary construction yard of about 5 acres will be located next to the main entrance road to the plant, off Highway 132 (see Figure 3-16). The construction yard will be used for the temporary storage of construction materials and fabrication of some project components. The construction yard will be fenced and will contain several temporary structures (trailers, buildings and sheds).

Water will be used as necessary to control fugitive dust produced by construction activities. Dust is not expected to be a serious concern at Puna, which receives an average of 120 inches of rainfall a year.

Visual impacts created by construction of the project will be mitigated by use of low-contrast paint schemes and landscaping with native plants (see Section 3.3). Cut-and-fill slopes, as well as any uncovered level areas, will be seeded or planted with native vegetation when construction is complete. Landscaping will be performed around the wellpad and power plant, and paint schemes will be used to blend in structures with the surrounding environment.

Removal of all the temporary structures from the construction yard site, the fence surrounding the site and surplus materials will take place after construction is completed and the full project has commenced commercial operation. Growth of natural plants will then be encouraged.

3.2.5.Operation and Maintenance

The operational life of the PGV Project facilities is estimated to be 35 years. The power plant and wellfield will be operated in a manner that protects human health and the environment. The facility staff will operate equipment, oversee production, and respond to emergencies. An important part of the operational phase of the project is regular maintenance and monitoring of both the power plant and the wellfield. Monitoring is discussed in Section 3.12 of this document.

Approximately 19 employees will be required for ongoing operation and maintenance of the facility. Most of the employees will be local residents.

The power plant and wellfield will operate continuously 24 hours per day, seven days per week. Qualified operators will be onsite at all times when the plant is operating. Routine maintenance will be conducted by workers during the normal daytime work shift. If repair work is required because of reduced power generation because of malfunction of part of the power plant, the maintenance work will continue 24 hours per day, seven days per week, until full power output can be resumed.

Wellfield maintenance will generally be performed without shutting off the flow of steam from any well. When this action cannot be taken or is unsafe, maintenance work for the wellfield will be phased so that the fewest possible number of wells will be closed down (shut in), and those wells will be shut in for a minimum time. Remedial drilling of a well, called well workover, is typically needed for proper wellfield maintenance. Well workovers are anticipated every 2 to 5 years for each well.

Scheduled power plant maintenance will be conducted for each steam turbine generating unit at intervals of one to two years, as needed. Thorough maintenance procedures, such as turbine disassembly and inspection, will be conducted during these planned outages. Because the plant output will be reduced during this scheduled maintenance, they will be coordinated with HELCO to ensure the maintenance of a reliable power system. Appropriately sized maintenance crews will be engaged around the clock, seven days per week, during this time. Work crews will work 8- to 12-hour shifts.

3.2.6. Plant Start-Up and Shutdown

The modular nature of the power plant allows a gradual start-up process as relatively small increments of power are synchronized to the grid, one at a time. The total process is relatively rapid due to the small moment of inertia and small volume to be heated during each step of the start-up process.
As start-up after a complete plant shut down begins, wellfield production will be 50 percent of the full steam flow, which will be released through the rock muffler. The power generation modules will enter production gradually, following the sequence

outlined below, and the flow to the rock mufflers will be reduced gradually until the power generating units are able to receive the 50 percent steam production.

The start-up of the generating modules typically begins with energizing the auxiliary systems needed for starting one OEC unit. These auxiliary systems include the air compressor, OEC lube and sealing oil pumps, condenser fans for one OEC unit, and working fluid circulation pump. The power for the auxiliary systems can be supplied either from the 250 kW diesel generator or from the utility grid.

To start an OEC unit, the steam turbine bypass will be opened, and the steam gradually let into the OEC vaporizer until it reaches full flow. After the start-up and synchronization of the first OEC unit, the power plant will supply its own power and also supply power to the grid. As more OEC units are started and synchronized, the wells will be opened up to allow more steam to flow from the wellfield.

The steam turbine paired with each OEC unit can be started as soon as its OEC unit is in operation. The steam will be gradually introduced into the steam turbines and increased until full-load steam turbine operation is achieved.

Shutdown of each OEC/steam turbine module will be handled in reverse order, i.e. first the steam flow to the steam turbine is gradually reduced while the steam turbine bypass is gradually opened. After the steam turbine is shut down, the steam to the OEC unit is gradually closed. When a complete shutdown plant is planned, the steam valve to the emergency steam release rock muffler will be opened gradually as the steam flow is reduced to about 50 percent of the design flow. Finally, either the diesel generator or the utility grid will be supplying the power to the auxiliaries after the last OEC unit has been shutdown.

Shutting down wells and returning them to service is generally minimized in geothermal operations around the world because it can cause damage to the wells and/or reduce their expected life.

3.2.7.Decommissioning

Decommissioning refers to the proper abandonment of the wellfield and removal of structures and equipment at the end of the useful life of the project. Economic and resource conditions will dictate when the facility should be decommissioned. The following steps will be taken during decommissioning:

- Structures and piping will be removed.

- Wells will be plugged with cement in accordance with procedures contained in the DLNR well drilling permits and regulations.

- Wellhead equipment and casing will be removed to below grade and the well casing capped.

- Roadways will be abandoned to the extent agreed upon with the landowner.

- The site will be regraded to approximate original contours, and the project area will be seeded or planted with natural vegetation, as appropriate.

3.3. Plot and Site Plans

This subsection provides "a preliminary plot or site plan of the property, drawn to scale, showing all existing and proposed uses and locations of structures including, but not limited to, drilling sites, wells, access roadways, water sources, waste water collection and disposal systems, the geothermal steam and/or brine collection and disposal systems, power plant(s) and electrical power distribution systems," as required by Rule 12.3(b)(2) part (C).

Preliminary site plans for the PGV Project area are presented in Figure 2-2 and Figure 3-4. The layout of a typical geothermal wellpad during drilling operations is presented in Figure 3-7, and that of a typical wellpad after completion of drilling, during normal operation, is shown in Figure 3-5. A plot plan showing the general arrangement of the PGV Project power plant site is presented in Figure 3-13. During construction of the power plant and wellfield, temporary working areas will be used for storage and fabrication of materials and equipment and for the construction administration offices, as shown in Figure 3-16. As described in Section 3.2, these plans depict existing and proposed uses and locations of structures including access roads, wellpads, collection and disposal systems, power plant, and electrical power distribution systems. Potable water will be supplied by the county system or a rain-catchment system. The intertie between the power plant and the electrical switchyard is also shown on the site plans.

As described in Section 3.2.1.1, all wells will be drilled from one of the six proposed wellpads, on an as-needed basis. The specific drilling target and wellpad location for each well will be identified in the drilling permit applications which are required by the Department of Land and Natural Resources (DLNR).

3.3.1. Visibility Criteria Used in Siting the Facilities

Visual concerns were an important criteria in choosing the location of the power plant and wellpads. The layout of the facility is designed to minimize the amount of land required for clearing. Cut-and-fill slopes will be engineered to minimize the visual impacts created by clearing and grading activities, so that the transition to the surrounding terrain appears more natural.

As discussed in Section 3.4, all proposed power plant facilities will be low-profile structures. None of the proposed structures will exceed 24 feet in height, with the exception of the ten 14-inch diameter isopentane emergency vent stacks which rise approximately eight feet above the air coolers. Similarly, all project lighting will be shielded from the direction of potential offsite visual receptors.

3.3.2. Site Landscaping

Landscaping will be installed around the power plant and wellpads to screen the industrial structures and equipment from view. The choice of vegetation will take into account the species' height and camouflaging ability. For compatibility, native plants will be used to the extent feasible. Almost all of the undeveloped lots in the surrounding subdivisions are densely forested and a vegetation screen can be left when they are developed.

Facility structures, including pipelines, will either be painted to blend into the surrounding environment or constructed of such material that their surface textures will blend in with surrounding vegetation. Dark green or dark gray colors will be used, depending on background vegetation and rocks. Reflective metal surfaces will be coated or screened with solid fencing.

Once planted landscaping matures, the vegetation will effectively screen the proposed plant structures.

3.4. Elevation of Structures

This subsection provides "preliminary elevation drawings of the proposed temporary and permanent structures," as required by Rule 12.3(b)(2) part (D).

Figure 3-7 is a view of a typical geothermal drilling rig during drilling operations, which shows the rig floor, derrick, drawworks, trailers and other equipment necessary for the drilling of each well. As stated in Section 3.2.1.3, each well will require, on average, approximately 45 days to drill, after which the drill rig will be moved to the next well, either on the same or another wellpad. During approximately the first two years after the start of construction, the drill rig will be in almost constant use. Once all the wells required for initial operation of the full 25 MW project are drilled, the drill rig will be utilized only for drilling makeup wells and well workovers, and when not in use will either be removed from the project area or stored onsite with the derrick retracted.

Figure 3-15 provides preliminary elevation drawings of the principal PGV Project power plant facility structures. The locations of the structures were identified in the site plan (Figure 2-2) and the power plant general arrangement (Figure 3-13). Preliminary dimensions and elevations of the main structures shown in the preliminary elevation drawing are also listed in Table 3-6. Detailed elevation drawings will be developed during the final engineering and design phase of the PGV Project. Figure 3-17 gives preliminary elevation drawings of the temporary structures which will erected during construction, as shown in Figure 3-16.

Table 3-6. Preliminary Dimensions of Principal Project Structures

Structure	Length (feet)	Width (feet)	Height[1] (feet)
Turbine Building (w/ switch gear)	130	30	24
Air Coolers	5 x 56	60	24
Control and Maintenance Building	170	40	20
Transformer	10	8	15
Standby Generator/Shed	25	20	15
Moisture Separators	6 dia		20
Brine Flash Separator	6 dia		12
Condensate Drum (horizontal)	10	6 dia	6
Water Tank	50 dia		24
NaOH Tank (10%)	25 dia		22
NaOH Tank (50%)(horizontal)	25	10 dia	10
Rock Mufflers	14 dia		14
Fence			6
Isopentane Tank (2 units)	30	7 dia	11
Isopentane Vent Stack (10 units)		14 inch	32
OEC Electrical Room (10 units)	20	12	10
OEC Unit (each)	40	8	12
OEC Vaporizer	46	4.5 dia	6
Wellpads	300	400	1
Wellheads	10	10	0
Switchyard	150	150	10

[1]Elevations above grade

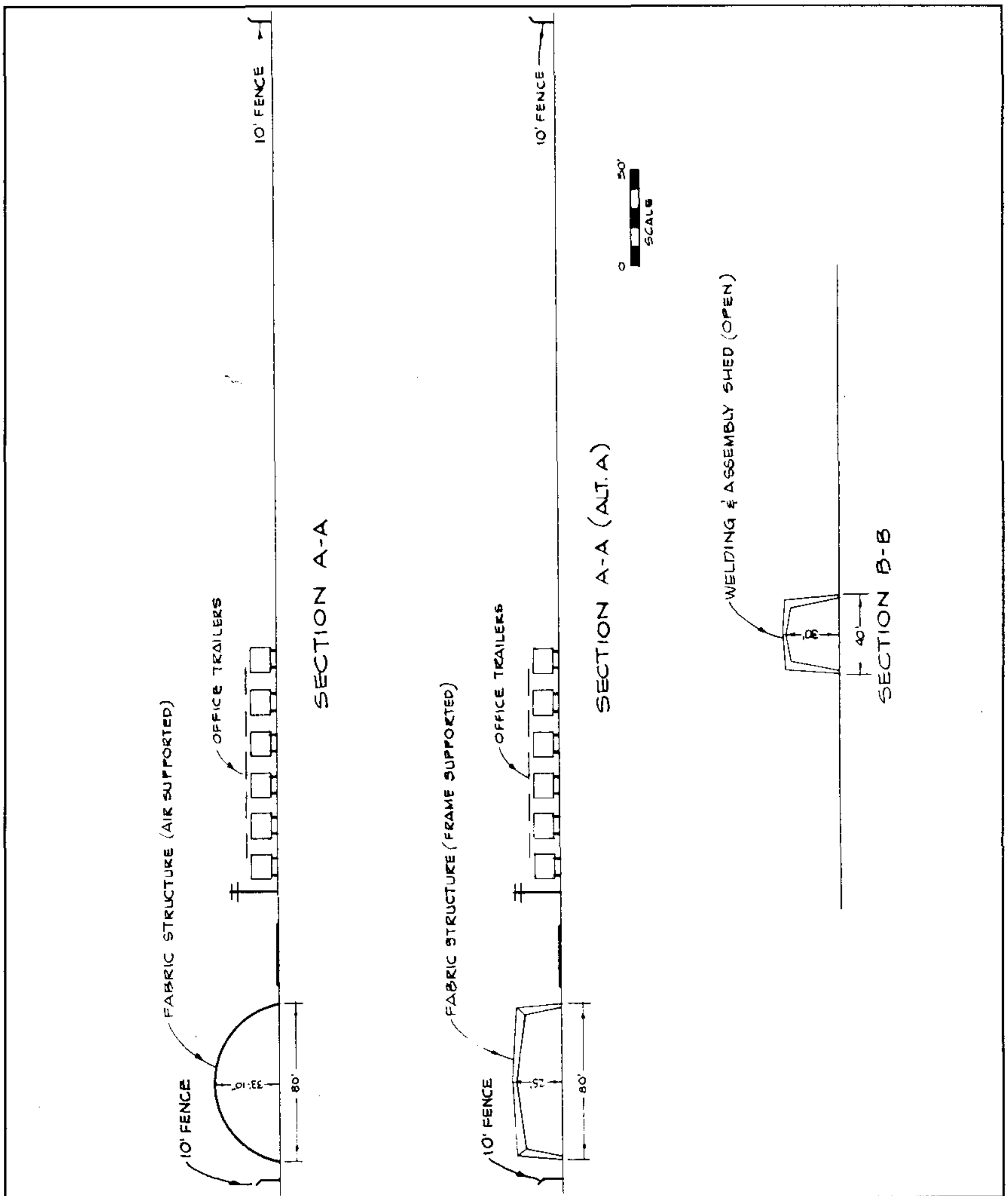


Figure 3-17. Preliminary Elevation Drawings of the Temporary Structures

An artist's rendering of the proposed PGV Project power plant and the immediately adjacent wellpad, which will show approximately how these facilities will appear once constructed, is currently under development. By utilizing smaller steam turbines, OEC units, and air coolers instead of cooling towers, the revised PGV Project will have a substantially lower profile (approximately 24 feet) than the previously proposed PGV Project (approximately 36 feet), and will not produce any water vapor plumes which would rise above the plant. To assist in the visualization of how the power plant will look, Appendix C provides photographs of other geothermal power plants which utilize OEC units as the principal generation units, some of which are also air cooled. Although the PGV Project power plant, like most other power plants, will have a unique design to accommodate the specifics of its location, geothermal resource, etc., the photographs of the power plants shown in Appendix C can be used to help envision what the PGV Project power plant will look like.

3.5.Wellhead Structures and Wellcasing Program

Rule 12.3(b)(2) part (E) requires a discussion of "the proposed locations and elevations and depths of all superstructures and drilling rigs, bottom hole locations, casing program, proposed well completion program, size and shape of drilling sites, and location of all existing and proposed access roads."

The proposed locations of the wellpads, the wellpad superstructures, the well completion program, the casing program,and the location of the access roads are all presented in Section 3.2.1. A detailed description of the proposed drilling and casing program is presented in Appendix B.

3.6. Surface Disturbance

This subsection discusses "areas of potential temporary and/or permanent surface disturbance, including, but not limited to, excavation and grading sites, the location of camp sites, airstrips, and other support facilities, excavation and borrow pits for roads and other construction activities," as required by Rule 12.3(b)(2) part (F).

About 6 percent of the 500-acre project area will be disturbed by the PGV Project. Approximately 24.5 surface acres will be required for the power plant, six wellpads, access roads, piping routes, switch yard, and brine pond. Another 5 acres will be used as a temporary construction yard. Nine of the acres have been cleared, and two more acres do not need clearing because they are covered with barren lava flow.

Most of the project area is relatively level, recently cultivated land or lava flows, and little grading will be required. Two wellpads, approximately four acres total, have already been graded, leaving 20.5 acres to be graded. The areas that will be disturbed are immediately around the power plant structures, the wellpads, along the piping routes, within the temporary construction yard, within the switchyard, and along the new access road off of Highway 132. The graded areas will be comparable in size to those created when homes are constructed in nearby subdivisions and far smaller than those associated with existing agricultural activities. A grading plan for each area will be submitted to the county prior to construction.

All construction materials and equipment will be kept within the graded areas or on internal roads within the project's boundaries. Adequate space is available onsite to use as a staging area for the construction. No offsite construction yards or bases are anticipated.

3.7.Disposal of Well Effluent and Other Wastes

This subsection provides "a written description of the methods for disposing of well effluent and other wastes," as required by Rule 12.3(b)(2) part (G).

Produced geothermal brines, steam condensate, and noncondensable gases will be disposed of through injection into the geothermal reservoir. Injection is essentially a closed loop disposal system since all geothermal fluids are returned to the geothermal reservoir. The injection system is discussed in further detail in Section 3.2.1.7, and the noncondensable gas control system, which feeds into the injection system, is discussed in Section 3.2.2.2.

The proposed project will also generate less than 200 gallons of domestic wastewater per day. Sewage disposal in the Puna District is by means of individual cesspools and septic systems. Current plans are to dispose of domestic wastewater onsite in cesspools. These cesspools are expected to perform satisfactorily due to the highly porous nature of the soils and underlying rock. Portable toilets may also be used during peak construction periods. No public drinking water sources would be affected by the proposed system.

3.8.Geologic Report

This subsection discusses "a geologist's report on the site and surrounding area's surface and subsurface geology, nature and occurrence of known or potential geological hazards and geothermal resources, surface and groundwater resources, topographic features of the land, and drainage patterns" as requested in Rule 12.3(b)(2) part (H).

As stated above in Section 3.2.1.1., the PGV Project area is located in a geologic region known as the Lower East Rift Zone (LERZ), found on the eastern flank of Kilauea Volcano. Kilauea is one of the world's most active volcanoes, and the LERZ is a conduit for lateral migration of basaltic magma flowing east-northeast from the caldera at the summit. The magma in this subsurface conduit provides the heat source for the high-temperature Puna geothermal reservoir, which in turn affects the groundwater resources in the area. The volcanic nature of the region requires consideration of the risks associated with volcanic eruptions, lava flows, and faulting.
Beneath the surface features of the LERZ, at depths below 8,000 feet, is thought to be a 5- to 15-mile wide dike complex, where temperatures approach 1,900°F, the melting point of basalt. A secondary magma chamber is thought to be located within the LERZ beneath the geothermal reservoir. The series of dikes convey heat to the high-temperature geothermal reservoir, a system of vertical to near-vertical fractures which contains a two-phase geothermal resource with temperatures as high as 600°F below 4,000 feet. Overlying the high-temperature geothermal reservoir is a relatively impermeable layer of capping rock, generally at depths of between 4,000 and 2,500 feet below the surface, although both the upper and lower boundaries of the

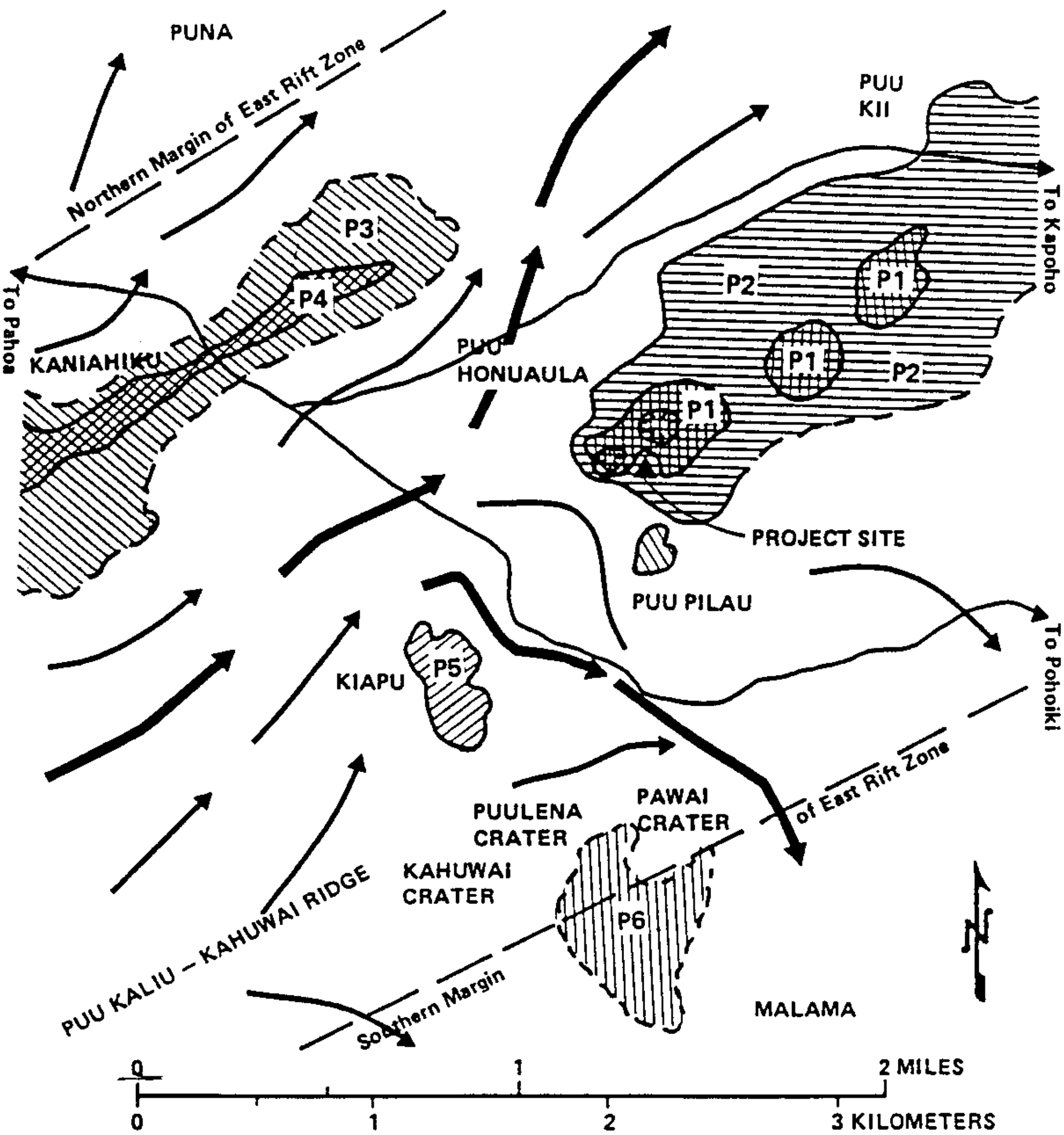
caprock are variable and dependent upon the local permeability (fractures). Figure 3-2 depicts a conceptual model of this Puna geothermal reservoir.

A zone of vigorous groundwater flow extends from the top of the generally impermeable caprock to the water table, approximately 600 feet below the surface. The groundwater in this upper aquifer is thermally and chemically influenced by natural leakage of geothermal fluids through the caprock from the geothermal reservoir below. The groundwater regime is charged by rainwater; as much as 120 inches a year fall at the site and percolate downward through the porous volcanic soil and rock. The dikes and faults of the LERZ affect the flow of this groundwater; natural leakage of geothermal fluids from the geothermal reservoir affects its quality. Sampled groundwaters in the site area, near where the fault traverses the LERZ, have temperatures ranging from 100 to 199°F, chloride-to-magnesium (Cl/Mg) ratios of 18 to 2000, silica content of 24 to 105 ppm, and total dissolved solids (TDS) concentrations of 762 to 11,700 ppm. This chemical signature led Ivonetti to classify the groundwater waters in this region as "geothermal." Upwelling "geothermal" waters form two plumes, one flowing parallel to the rift to form a mixed groundwater region at Kapoho Crater, the other forming a broad plume that follows topography, discharging as warm springs and seeps along the Puna coast.

The proposed project must be designed for volcanic and seismic hazards. Since the area has been subject to lava flows as recently as 1955, 1960, and 1961, the risks of renewed flows was considered in siting the proposed facilities. The power plant site is on relatively high ground (elevation 670 feet), approximately 40 feet above the surrounding terrain at the southern base of Puu Honuaula and the adjacent puu, which places it at a relatively low risk of inundation from uprift lava flows (see Figure 3-18). Wellpads B, C, and D are at higher elevations (680 to 720 feet), and thus lower risk, while the wellpads to the southwest, Wellpads A, E, and F, are at elevations of 620 to 640 feet, which place them at higher risk. All the geothermal wellheads will be placed in cellars that can be readily filled with volcanic cinders to reduce the chances of structural failure in the event of a lava flow. The other facilities will be designed to be isolated as much as possible and/or removed or abandoned in the event they are seriously threatened by a flow capable of inundation. Close coordination with the U.S. Geologic Survey and the Hawaii Institute of Geophysics will ensure as early a warning of anticipated volcanic activity as possible.

Volcanic and tectonic activity also poses risks of fissuring, ground acceleration, surface deformation, and subsidence. The maximum anticipated ground acceleration is 0.4 g, and the proposed facilities will be designed for movements in excess of this, in conformance with Seismic Zone 4 requirements. The steam and brine pipelines will be designed with expansion loops to accommodate thermal stress, which may also minimize the effects of fissuring, subsidence, and ground swelling which could occur in the project area.

The withdrawal of geothermal fluids is not likely to induce subsidence because the geothermal reservoir consists of dense, structurally competent basalts which resist compaction. In addition, because all geothermal fluids will be injected back into the geothermal reservoir, there will be no significant reductions of reservoir pressure. The injection of fluids into the geothermal reservoir may have the possibility of increasing



Map showing relative risk of lava flow incursions. Arrows show likely directions of flow of lavas in future eruptions. The most likely paths of flow are shown with thick arrows. P1 marks areas with lease risk of lava incursion and P6 marks areas of intermediate risk. Unshaded areas are those of greatest risk. (After Slemmons, 1981)

Figure 3-18. Puu Honuaula Area Volcanic Risk Levels microseismic activity, but the possible levels of induced activity are significantly less than currently experienced in the area, which is one of the most seismically active regions in the world.

3.9. Background Meteorology, Air Quality and Noise Levels

This subsection presents "pre-exploration meteorological ambient air quality and noise level measurements that demonstrate the potential effects on surrounding properties through air quality and noise analysis," as required by Rule 12.3(a)(2) part (I).

Preconstruction site meteorology, ambient air quality, and noise level measurements have previously been taken in the project area to provide the basis for air quality and noise level impact analysis. PGV has conducted meteorology and air quality monitoring studies in the Puna region since 1981. An environmental noise survey was conducted at the PGV site during early September 1986.

The assessment of the effects of the emissions of H_2S and particulates from the proposed PGV Project wellfield and the proposed PGV Project power plant on the local ambient air quality involves a comparison of the estimated impacts with the proposed Hawaii State Ambient Air Quality Standard (SAAQS) for H_2S, the existing SAAQS for total suspended particulates (TSP), and the National Ambient Air Quality Standard (NAAQS) for particulates less than 10 microns in diameter (PM_{10}).

3.9.1.Meteorology

PGV has conducted comprehensive meteorology monitoring studies of the "Woods" site (1.1 miles northwest of the power plant site) since April 1982 (see Figure 3-19). PGV also analyzed annual wind speed distribution data at the "Woods" site for the period October 1982 through September 1983 and these data were used in the air dispersion modeling. These data show that the prevailing wind flow is from the west during the nighttime and from the north to northeast during the daytime. The nighttime westerly winds shown derive from downslope flows due to thermal gradients on adjacent terrain while the north-to-northeast daytime winds derive from the trade wind flow.

3.9.2.Air Quality

3.9.2.1.Background Air Quality

An H_2S air quality data base is available to establish the background air quality for the area surrounding the project. The ambient monitoring stations are shown in Figure 3-19 and are described below:

- The "Schroeder" site is located approximately 1.3 miles (2 km) south-southwest of the HGP-A well site. H_2S ambient monitoring began in March 1981. This was the first H_2S monitoring site to be established;

- The "Hess" site is located approximately 1.3 miles (2 km) southwest of the HGP-A well site. This station began H_2S monitoring in July 1982, and was discontinued in January 1984;

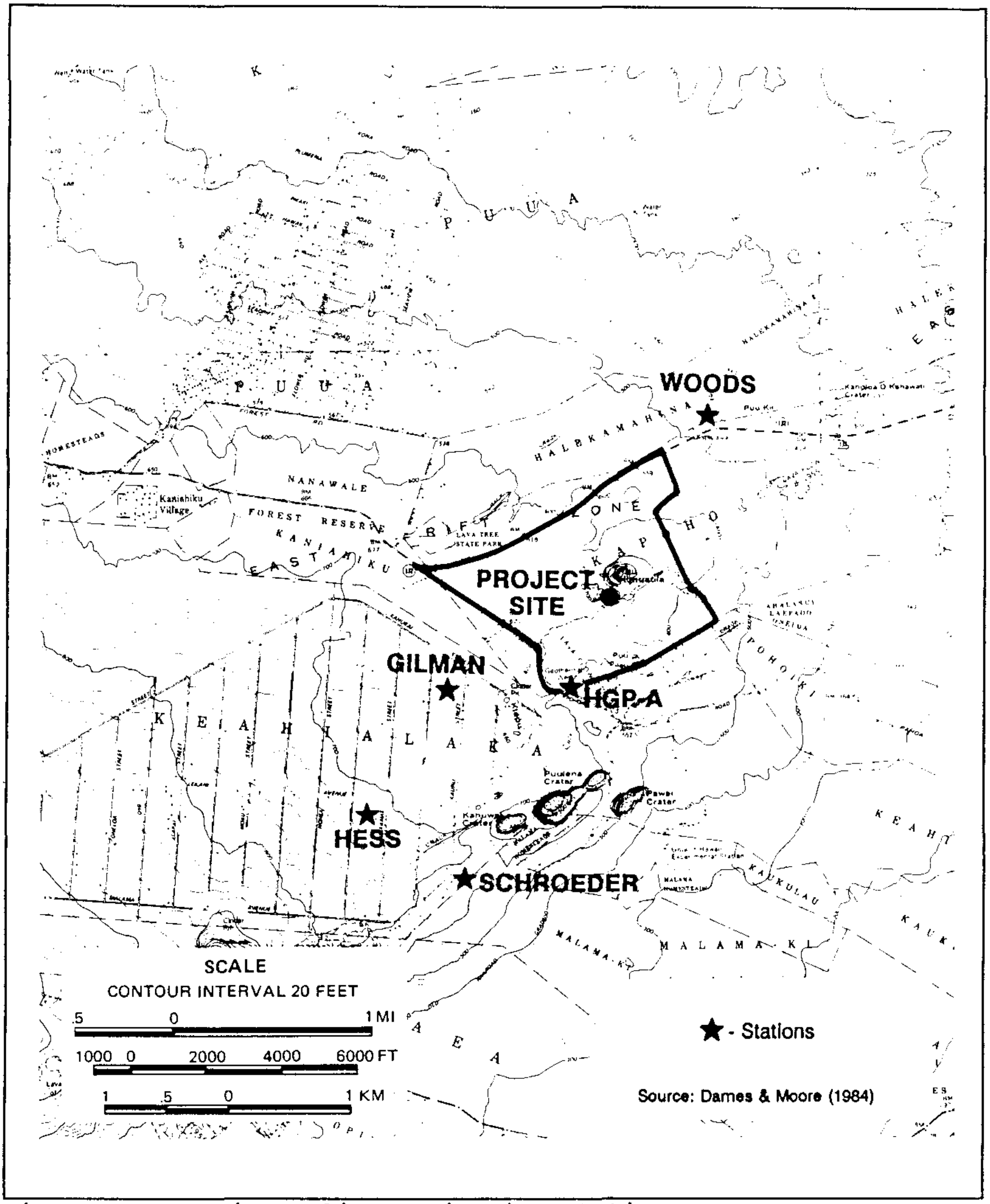


Figure 3-19. Air Quality Monitoring Stations

- The "Gilman" site is located approximately 0.6 miles (1 km) west of the HGP-A well site. Monitoring began in 1981 with comprehensive data retrieval in April 1982; and

- The "Woods" site is located approximately 1.1 miles (1.7 km) north of the HGP-A well site. Monitoring began in 1981 with comprehensive data retrieval in April 1982.

NEA, Inc. and Alpha Micro Systems, Inc. have recorded ambient H_2S concentrations for the Hawaii Department of Planning and Economic Development (Dames & Moore, 1984). Data collected and reported through 1983 for the "Schroeder", "Gilman", and "Hess" sites and through June 1987 for the "Woods" site are shown in Table 3-7.

These data indicate that H_2S ambient levels are below 14 $\mu g/m^3$ (0.010 ppmv) from all stations over the past six years about 98 percent of the time. The highest H_2S levels were 67.2 $\mu g/m^3$ (0.048 ppmv) at the "Schroeder" site in the early 1980s. This site is located southwest of the HGP-A well site.

Data for 1988 from three stations, "Gilman," "Schroeder," and "Woods," are also included in Table 3-7. These data show the current ambient air quality and reflect the present level of abatement on the 3 MW HGP-A project. The average concentration of all three air quality stations in 1988 was 3.5 $\mu g/m^3$ (0.003 ppmv), which is at or below the detection limit of the monitoring equipment. In 1988, only two hours exceeded 14 $\mu g/m^3$ (0.010 ppmv), one of which represents a reading during a period of HGP-A H_2S equipment malfunction. Higher levels were recorded at the "Fenceline" station at the HGP-A boundary. The 1988 "Fenceline" data showed an average concentration of 11 $\mu g/m^3$

Table 3-7. Summary of H_2S Air Quality Monitoring Data

	"Woods"[1]		"Gilman"[1]		"Schroeder"[1]		"Hess"[1]	
Time	Highest ($\mu g/m^3$)	2nd Highest ($\mu g/m^3$)	Highest ($\mu g/m^3$)	2nd Highest ($\mu g/m^3$)	Highest ($\mu g/m^3$)	2nd Highest ($\mu g/m^3$)	Highest ($\mu g/m^3$)	2nd Highest ($\mu g/m^3$)
March 1981-June 1987	22	21	29	22	67	29	19	7
January 1988 - December 1988	19	7	22	10	9	9	N/A	N/A

[1]Locations of the air quality monitoring sites are presented in Figure 3-19.

(0.008 ppmv), with the two highest hourly readings being 25 $\mu g/m^3$ (0.018 ppmv) and 24 $\mu g/m^3$ (0.017 ppmv). These H_2S ambient levels can be compared with the proposed ambient 1-hour standard of 139 $\mu g/m^3$ (0.1 ppmv).

TSP has been monitored using high volume samplers at two locations in Puna. The first location is the Bishop Estate Leasehold, about 3 miles southwest of the power-plant site; the second is the visitor center of the Hawaii Volcanoes National Park about 13.2 miles northwest of the power plant site. Data from the Bishop Estate Leasehold showed that the 14 biweekly samples between December 1982 and March 1983 averaged a 24-hour TSP level at 20 $\mu g/m^3$. The highest value at the visitor center was 39 $\mu g/m^3$. These TSP values can be compared to the 24-hour average SAAQS of 150 $\mu g/m^3$

PM_{10} has been monitored at the Hawaii Volcanoes National Park since March 1988. Data from 29 samples collected between March 1988 and August 1988 showed a 24-hour average PM_{10} concentration of 7.5 $\mu g/m^3$, with the two highest values 27.1 $\mu g/m^3$ and 16.9 $\mu g/m^3$. These values can be compared to the federal 24-hour PM_{10} NAAQS of 150 $\mu g/m^3$.

3.9.2.2.Air Quality Impact Analysis

The air quality impact analysis considers wellfield sources, power plant sources, and combined sources. Impacts of H_2S and particulate emissions from the Puna geothermal plant were assessed using the EPA dispersion model COMPLEX I. Individual wellfield sources were modeled as point sources.

For the wellfield, sources were modeled for Wellpads E and F, as these pads are closest to the property boundary and to the local residences along the Pahoa-Pohoiki Road. For combined source cases, power plant sources were combined with Wellpad E sources because, of the two wellpads, Wellpad E is closer to the property boundary.

Two sets of receptors were used for the COMPLEX I modeling; a set of polar coordinates, internally generated receptors, and a set of discrete receptors. These are the same receptors used for the previous modeling analysis. Receptors were located at 36 points on each of the 7 rings about the power plant site. Receptor rings were located at distances of 0.7 to 4.5 km from the center of the power plant site. An additional 141 receptors were located in a rectangular coordinate grid south-southwest and west-northwest of the power plant site. This grid included 21 receptors along the property boundary. Only impacts at receptors on or outside of the property boundary are considered in the impact assessment.

3.9.2.2.1. Emission Rates

Table 3-8 and Table 3-9 list the annual emission rates for each of the potential pollutants from the PGV wellfield and the PGV power plant respectively, for which there is an NAAQS or SAAQS or which the DOH Air Pollution Control Administrative Rules have adopted a significance level.

Table 3-9 also includes the total annual emissions for the PGV wellfield during field development and after the wells are connected to the power plant. The wellfield emissions after connection to the power plant are based on drilling and testing of three wells a year, the maximum level of activity that is expected to occur concurrently with power plant operations. Table 3-9 also includes isopentane (C_5H_{12}) emissions, even though it is not a criteria pollutant and no significance level has been established for it.

Table 3-10 compares the total annual emissions of pollutants from the wellfield and the power plant with the significance levels established by Section 11-60-1 of the DOH Air Pollution Control rules. As Table 3-10 indicates, the proposed PGV wellfield and the proposed PGV power plant will not emit significant amounts of any pollutant regulated by the Clean Air Act.

Table 3-8.Potential Emissions From Wellfield Sources

	Well Drilling	Well Venting	Well Testing	Pipeline Cleanout	Fugitive Emission	Power Plant	Total
				(tons/year)[1]			
Prior to Connection to Power Plant[2]							
H_2S	0.17	1.87	4.25	0.20	N/A	N/A	6.49
TSP	0.17	3.20	1.01	0.003	N/A	N/A	4.38
Hg[3]	0.00001	0.00007	0.003	0.00008	N/A	N/A	0.0034
NOx[4]	35.4	N/A	N/A	N/A	N/A	N/A	35.4
CO[4]	7.4	N/A	N/A	N/A	N/A	N/A	7.4
SOx[4]	5.4	N/A	N/A	N/A	N/A	N/A	5.4
After Connection to Power Plant[5]							
H_2S	0.06	0.70	2.12	N/A	0.31	0.22	3.41
TSP	0.06	1.20	0.50	N/A	0.00	0.07	1.83
Hg[3]	0.000003	0.00002	0.002	N/A	N/A	0.00008	0.002
NOx[4]	13.3	N/A	N/A	N/A	N/A	N/A	13.3
CO[4]	2.8	N/A	N/A	N/A	N/A	N/A	2.8
SOx[4]	2.0	N/A	N/A	N/A	N/A	N/A	2.0

[1]Emissions data is based upon composite Puna geothermal reservoir fluid samples and the source operation and emissions data presented in Section 4.

[2]Assumes 8 wells drilled (6 production, 2 injection) with 6 wells vented and tested at 90,000 lb/hr steam for 240 hours.

[3]Assumes all mercury in the brine is emitted with the steam, an extremely conservative assumption.

[4]Three 440 kW diesel generators operation at an average load factor of 0.3 during drilling. One 440 kW diesel generator on standby.

[5]Assumes 3 wells drilled or reworked and tested at 90,000 lb/hr steam for 240 hours.

Table 3-9. Potential Emissions from Power Plant Sources

Pollutant[1]	Piping Manifold	Rock Muffler	Diesel Generator[2]	Isopentane Release[3]	Total
	tons/year				
H_2S	0.09	0.59	N/A	N/A	0.68
TSP	0.001	0.17	0.03	N/A	0.20
Hg	N/A	0.0012	N/A	N/A	0.0012
CO	N/A	N/A	0.08	N/A	0.08
NO_x	N/A	N/A	0.33	N/A	0.33
SO_2	N/A	N/A	0.03	N/A	0.03
C_5H_{12}	1.75	N/A	N/A	2.5	4.25

[1]Emissions data based upon composite Puna geothermal reservoir fluid samples and the source operations and emissions data presented in Section 4.

[2]Based on 50 hours of operation of the 250 kW generator per year, 20 hours operation of the 315 hp firewater pump.

[3]Based on two emergency releases of 2,500 lb isopentane a year.

The PGV wellfield, nevertheless, will employ BACT to the wellfield sources of emissions in order to maintain the proposed low rates of emissions and to meet the Department of Health rules. The 25 MW power plant will achieve low emission rates by eliminating the cooling towers which were a major source of emissions, and by injecting all but fugitive geothermal fluids and gases back into the reservoir.

Table 3-10. Comparison of Project Emissions with Significance Levels

Pollutant	Power Plant[1] Emissions	Wellfield[1] Emissions	Significant[2] Emission Rate
		(tons/year)	
H_2S	0.68	6.49	10.0
TSP	0.20	4.38	25.0
Hg	0.0012	0.003	0.1
CO	0.08	16.18	100.0
NOx	0.33	101.8	40.0
SO_2	0.03	9.0	40.0

[1]Emissions data is based upon composite Puna geothermal reservoir fluid samples and the source operation and emissions data presented in Attachment P-10 in Section 2.

[2]Significance levels based definition of significant on Section 11-60-1 of Chapter 60.

3.9.2.2.2.Impacts of Wellfield Sources

The maximum predicted impacts from well drilling, well venting, well flow testing, pipeline cleanout and fugitive emissions for H_2S and particulates at the receptor locations on and outside of the project boundary are given in Table 3-11. The maximum model impact (i.e., most conservative) for all sources modeled is based on modeling with the October 1982 through September 1983 meteorological data base.

The maximum 1-hour H_2S project impact modeled was caused by well cleanout venting. Since these impacts are not acceptable, PGV

Table 3-11. Maximum H_2S Concentrations from Wellfield Operations

		Wellpad E			Wellpad F		
Wellfield Source	Rank	1-Hour Average H_2S Concentration ($\mu g/m^3$)	Location with respect to Wellpad E: Azimuth (deg)	Location with respect to Wellpad E: Distance (km)	1-Hour Average H_2S Concentration ($\mu g/m^3$)	Location with respect to Wellpad F: Azimuth (deg)	Location with respect to Wellpad F: Distance (km)
Well Drilling	1	48	202	0.2	41	233	0.3
	2	46	162	0.3	35	220	1.5
Well Venting[1]	1	77.3	266	0.5	69.8	253	0.8
	2	75.3	208	0.8	69.7	204	0.7
Well Flow Testing	1	22	162	0.2	20	233	0.3
	2	19	226	0.3	13	228	2.6
Pipeline Cleanout[12]	1	81.6	312	0.7	81.6	312	0.7
	2	79.9	302	0.7	79.9	302	0.7
Fugitive Emissions	1	4	162	0.2	6	94	0.1
	2	3	226	0.3	3	233	0.3

[1]Venting during daytime (neutral, unstable) periods with windspeeds ≥ 4 m/s (8.9 mph).

[2]Cleanout emissions from all pipelines will be emitted at the power plant site.

Source: Aerometric Monitoring, Inc.

reviewed the meteorological data to determine what conditions would provide adequate dispersion of vented H_2S emissions. The maximum impact of venting is 77 $\mu g/m^3$ H_2S which occurs when vertical cleanout venting takes place at daylight neutral or unstable periods in which windspeed is greater than 4 m/s (8.9 mph). Based upon this analysis, PGV plans to schedule well venting only during those periods when winds equal or exceed 4 m/s and are expected to continue to do so. The same criteria will be applied to pipeline cleanout emissions.

The COMPLEX I model was also run to estimate impacts from well cleanout venting at the H_2S monitoring stations ("Gilman", "Woods", "Hess", Schroeder"). With the meteorological restriction of daytime, windspeed ≥4 m/s, the highest 1-hour H_2S concentration at any of the monitoring sites was 63.9 $\mu g/m^3$ at the "Gilman" site.

The 24-hour average maximum PM_{10} and TSP concentrations from Wellpad E sources were 11.0 $\mu g/m^3$ and 22.0 $\mu g/m^3$ respectively for well venting. Table 3-11 lists maximum estimated concentrations from the wellpads closest to the property boundary and to scattered residences along Pahoa-Pohoiki Road. The impacts from other wellpads will be less at the property boundary because they are further away.

3.9.2.2.3.Impacts of Power Plant Sources

During normal operation, the PGV power plant emits only a negligible amount of H_2S. The maximum predicted impacts for H_2S from fugitive emissions and the emergency steam releases and their receptor locations are given in Table 3-12. The maximum model impact (i.e., most conservative) is based on modeling with

Table 3-12. Locations of Highest and Second Highest H_2S Concentrations from Power Plant Sources

Power Plant Source	Rank	Maximum 1-Hour Average H_2S Concentration $\mu g/m^3$)	Azimuth (deg)	Distance (km)
Fugitive Emissions	1	0.1	195	0.7
	2	0.1	218	0.8
Emergency Steam Release	1	32.7	228	4
	2	25.3	225	2

the October 1982 through September 1983 meteorological data base.

The maximum 1-hour H_2S project impacts were 32.7 $\mu g/m^3$, caused by the first hour of emergency steam release and occurred at high terrain receptor locations about 4.4 miles southwest of the power plant site.

3.9.2.2.4.Combined Impact of Emission Sources

PGV will schedule its activities at the PGV Project to minimize the effects of simultaneous emissions of sources within the wellfield and at the power plant. The power plant will not be operating during the period of peak wellfield development. During the period of peak wellfield development, only one drilling rig is expected to be operating. However, the drilling of one well with aerated water or mud may overlap with the testing period of another well. Well venting, the activity which has the greatest impact on air quality, will be scheduled so that it does not coincide with the drilling with aerated water or mud or testing of another well or with pipeline cleanouts. Similarly, prior to start-up, the pipeline cleanouts will be scheduled so that they do not coincide with drilling with aerated water or mud, or well venting or flow testing of the wells.

When the power plant begins full operation, the only sources of emissions will be the fugitives from the wellfield and the power plant area. These emissions are conservatively estimated to be less than 0.1 lb/hr H_2S, and this situation is expected to occur more than 99 percent of the time. If an emergency steam release occurs, the power plant will cease operating, and the power plant fugitives will stop, but the wellfield fugitive emissions will continue.

Eventually, makeup well drilling and well workovers will occur in combination with power plant operations. Again, these wells will be drilled one at a time, with no more than three wells drilled during one year. Thus, well drilling (inadvertent releases during drilling with aerated mud or water) and testing emissions could coincide with power plant operations, as could well drilling with aerated mud or water and well venting emissions. The scenario with the greatest potential for combined emissions is one in which an emergency steam release occurs when a makeup well is being tested and another well is being drilled with aerated mud or water. The probability of this worst case scenario occurring is estimated at less than one in one million.

Four scenarios of combined emissions were modeled using the COMPLEX 1 model and the receptors discussed in Section 3.9.2.2. These scenarios are as follows:

Case 1: Normal Operations - Power Plant and Wellfield Fugitives

Case 2: Power Plant and Wellfield Fugitives, Well Drilling, Well Testing

Case 3: Power Plant and Wellfield Fugitives, Well Venting

Case 4: Emergency Steam Release, Wellfield Fugitives, Well Drilling, Well Testing

The results of the modeling for maximum 1-hour H_2S from the combined power plant and wellfield emissions, are presented in Table 3-13. Annual average concentrations are not shown for Case 3 because the total duration of this scenario is less than 24 hours a year.

3.9.2.2.5.Proposed SAAQS Increment Assessment

The proposed DOH geothermal power plant regulation requires that the maximum allowable increase in H_2S concentrations in ambient air above natural background levels consider all stationary sources (except geothermal wells during testing and routine maintenance) in the area affected by the proposed power plant. Table 3-14 compares the second highest modeled impact of the proposed PGV power plant (during normal operation) and the first hour of emergency steam release and the second highest monitored impact in the affected area, and compares this total to the proposed state allowable increment. The monitored H_2S levels overstate the HGP-A impacts as they also contain some background concentrations from scattered natural sources in the area. The high monitored levels also probably show the influence of periods

Table 3-13. Maximum H_2S Concentrations for Combined Sources at Power Plant and Wellpad E

Case	Rank	Maximum 24-Hour Averages / Maximum 1-Hour H_2S Concentration ($\mu g/m^3$)
Case 1		
Normal Operations	1	6
(Power Plant and	2	3
Wellfield Fugitives)		
Case 2		
Normal Operations +	2	76
Well Drilling and	2	68
Testing		
Case 3[1]		
Normal Operation +	1	83
Well Venting	2	78
Case 4		
Emergency Steam	1	107
Release + Well	2	99
Drilling and		
Testing + Wellfield		
Fugitives		

[1]Annual average for Case 3 not applicable because dominated by short period (1 day) events of drilling and venting. Venting limited to daytime periods (neutral or unstable) with windspeeds ≥4 m/s.

Source: Aerometric Monitoring, Inc.

Table 3-14. SAAQS Evaluation for H_2S Maximum Allowable Increment

Pollutant	Averaging Period	2nd Highest Monitored Concentration ($\mu g/m^3$)	2nd Highest Monitored Concentration[b] ($\mu g/m^3$)	Maximum Concentration ($\mu g/m^3$)	Maximum Allowable Increment ($\mu g/m^3$)
H_2S-Normal Operation	1-hour	10	0.1	10.1	35

Notes:

[a]The second highest monitored 1-hour H_2S concentration for normal operation is based on the 1988 H_2S monitoring data excluding data thought to reflect equipment malfunction.

[b]Second highest modeled concentration based on data presented in Table 3-12.

when there were malfunctions of the H_2S abatement system or emergency steam releases at HGP-A. The second highest modeled and monitored concentrations (which occur at different locations)give a conservative estimate for comparison to an increment that, by regulation, may be exceeded once a year at any one location.

Table 3-15 shows that the ambient air quality impact of the proposed PGV Project will be within the allowable increment for H_2S established by the proposed air quality rules.

3.9.2.2.6.NAAQS and Proposed SAAQS Assessment

The air quality impact assessment consists of a comparison of estimated impacts to the National Ambient Air Quality Standards (NAAQS) for particulates and proposed State Ambient Air Quality Standards (SAAQS) for H_2S. For comparison to the NAAQS and the proposed SAAQS the second highest concentration from the ambient air quality monitoring data is added to the second highest value from the modeling results. This method for the NAAQS and SAAQS will result in a conservative estimate because the assumption is made that both the second highest monitored value and second highest modeled impact occur at the same time and location.

The results of the second highest H_2S and particulates monitored values and modeled impacts are given in Table 3-15. The combined concentrations are less than the proposed H_2S SAAQS of 139 $\mu g/m^3$ and less than the 24-hour and annual average SAAQS for TSP and NAAQS for PM_{10}.

Table 3-15. SAAQS and NAAQS Evaluation for H_2S and Particulates

Total Pollutant	Averaging Period	2nd Highest Monitored Concentration[1] ($\mu g/m^3$)	2nd Highest Modeled Concentration[2] ($\mu g/m^3$)	Maximum Concentration ($\mu g/m^3$)	SAAQS ($\mu g/m^3$)	NAAQS ($\mu g/m^3$)
H_2S (proposed)	1-hour	19.0	99.0	118.0	139	
PM (TSP)	24-hour	39.0	22.0	61.0	150	-
	Annual Arithmetic Average	20.0	<1	<21	60	-
PM (PM_{10})	24-hour	16.9	12	28.9	-	150
	Annual Arithmetic Average	7.5	<0.3	<7.8	-	50

Notes:
[1]The second highest monitored H_2S concentration based on data presented in Table 3-14. The second highest 24-hour and annual average monitored PM_{10} concentrations are based on data recorded at the Hawaii Volcanoes National Park visitor center and the Bishop Estate Leasehold during the period December 1982 through March 1983. The PM_{10} annual average concentration is based on the average of 29 samples taken March-August 1988. The 24-hour average TSP concentration is the highest monitored value and the annual average TSP concentration is based on the average of 14 biweekly samples taken during that period.

[2]The second highest modeled 1-hour H_2S concentration is based on Case 4 presented in Table 3-13.
The second highest particulate concentrations are based on Case 3; the annual average PM_{10} concentrations are based on Cases 2 and 4; annual TSP concentrations are from Case 1.

3.9.3.Noise

Currently, no noise ordinance with numerical limits is applicable to the site. The County of Hawaii Planning Department has developed Geothermal Noise Level Guidelines from a study of noise in the Puna District (Darby-Ebisu and Associates, Inc., 1981). These guidelines consider 55 dBA during daytime (7:00 a.m. to 7:00 p.m.) and 45 dBA during nighttime (7:00 p.m. to 7:00 a.m.) as satisfactory sound levels for residential areas. The allowable noise limit for impact noise (noise of short duration, typically less than one second, and caused by impacts of pipes, tools, etc.) is 10 dBA higher than the overall daytime and nighttime limits. The allowable noise levels may not be exceeded more than 10 percent of the time in any 20-minute period.

3.9.3.1.Background Noise Monitoring

An environmental noise survey was conducted in early September 1986 at four locations at the PGV site to determine ambient noise levels during weekday periods. Two battery-powered noise monitoring systems were used to measure the ambient noise levels for 24-hour periods at the four locations.

Two of the locations were on residential properties located south and southwest at approximately 0.5 and 1 mile, respectively, from the PGV proposed power plant site. These residence locations were:

-"Brees" Station, lot 54, Lanipuna Gardens, Lauone

-"Gilman" Station, residence, Kaupili Street

The two remaining monitoring locations were on the PGV site, one at Wellpad A and the other at Wellpad B.

Background noise levels during the survey period on and around the PGV site ranged from L_{eq} values of 34.2 dBA (7 p.m. at "Brees" Station) to 53.2 dBA (5 a.m. at "Gilman" Station), which exceeded the County noise guidelines of 45 dBA (see Table 3-16). The relatively high background noise was due to moderate wind (6 mph or greater) and moderate to heavy rain conditions (wind at Hilo averages 7.2 mph year-round and annual rainfall is approximately 120 inches). Early morning rains were observed each day during this survey period and localized rain showers of short duration were observed during daytime hours.

Table 3-16. Range of Background Hourly L_{90} and Average L_{eq} Sound Levels

	On-Site Locations		Off-Site Location	
	Wellpad A (dBA)	Wellpad B (dBA)	Brees Station (dBA)	Gilman Station (dBA)
	Hourly L_{90} Sound Levels			
Daytime	35 to 38	32 to 39	32 to 40	32 to 40
Nighttime	36 to 39	35 to 41	34 to 35	38 to 51
	Hourly Average L_{eq}[a] Sound Levels			
Daytime	37 to 64	35 to 54	34 to 51	39 to 51
Nighttime	38 to 44	39 to 47	36 to 46	41 to 53

[a]Rounded to the nearest dB level.

The prevalent noise during daytime hours is from distant and local traffic, wind, birds, and insects. Noise from operation of the HGP-A facility, located on Pahoa-Pohoiki Road, just south of the PGV site, was barely audible at the PGV onsite monitoring locations (Wellpads A and B) and inaudible at the two off-site resident monitoring stations. (Subsequent experience has shown that the HGP-A facility is, at times, audible at the "Gilman" Station.)

3.9.3.2.Noise Impact Analysis

Development of the geothermal facility will occur in stages. During various stages noise can be expected from the following sources: construction, traffic, well drilling, flow testing and venting, and plant operation.

Construction noise will be caused by power equipment and heavy equipment. Temporary construction noise levels may range up to 89 to 93 dBA at 50 feet. The loudest anticipated noise levels will be backup alarms, which are standard safety features of construction equipment and required to be clearly audible above construction noise. Construction noise will, as much as possible, be restricted to weekday, daylight hours.

The traffic associated with construction of the PGV plant and drilling operations is estimated to be about 35 vehicle round trips per day. Using worst case assumptions of traffic traveling at an average speed of 30 to 40 mph up a grade, the hourly calculated average traffic noise would be between 30 and 40 dBA at a distance of 200 feet from the roadway.

Noise generated during well drilling operations will be temporary. The primary noise sources will be the mud circulation equipment, generators and engines, all of which are located on the drilling rig and are acoustically insulated. Well drilling typically produces noise levels of 64 to 75 dBA at 50 feet. Noise levels from each of the six proposed wellpad locations are predicted to attenuate with distance and reach 45 dBA within 0.6 mi (1 km). Noise levels from drilling at Wellpad E were predicted to range from 46 to 50 dBA at the Kapoho and Pohoiki-Bay Estates residents (see Figure 3-20). The levels at the Lanipuna Garden residences were predicted to range from 46 to 51 dBA from drilling at Wellpad F (see Figure 3-21) and from 45 to 48 dBA from drilling at Wellpad B. All other well drilling noise levels were expected to be less than 45 dBA at the nearest resident receptors. These projections do not consider the sound attenuation of foliage, barriers, and terrain; and PGV has proposed additional mitigation measures, including placing acoustical enclosures around drilling rig engines, to reduce noise levels from drilling (see Section 3.10.5.2).

Remedial well workover operations, which may occur intermittently approximately 5 years from the initial well drilling, will use air as the circulating medium instead of drilling muds. The noise from drilling with aerated water or mud is expected to be higher due to the air compressors. The noise of escaping steam is added to the air compressor noise when steam is encountered. A muffling system will be utilized to reduce steam venting noise to a level 10 dBA above that of the air compressors. It may be possible to further reduce routine steam venting noise levels to that of the air compressors and attempts will be made to do so wherever feasible. Well workovers may last 5 days, but generally not longer unless problems or unusual circumstances occur.

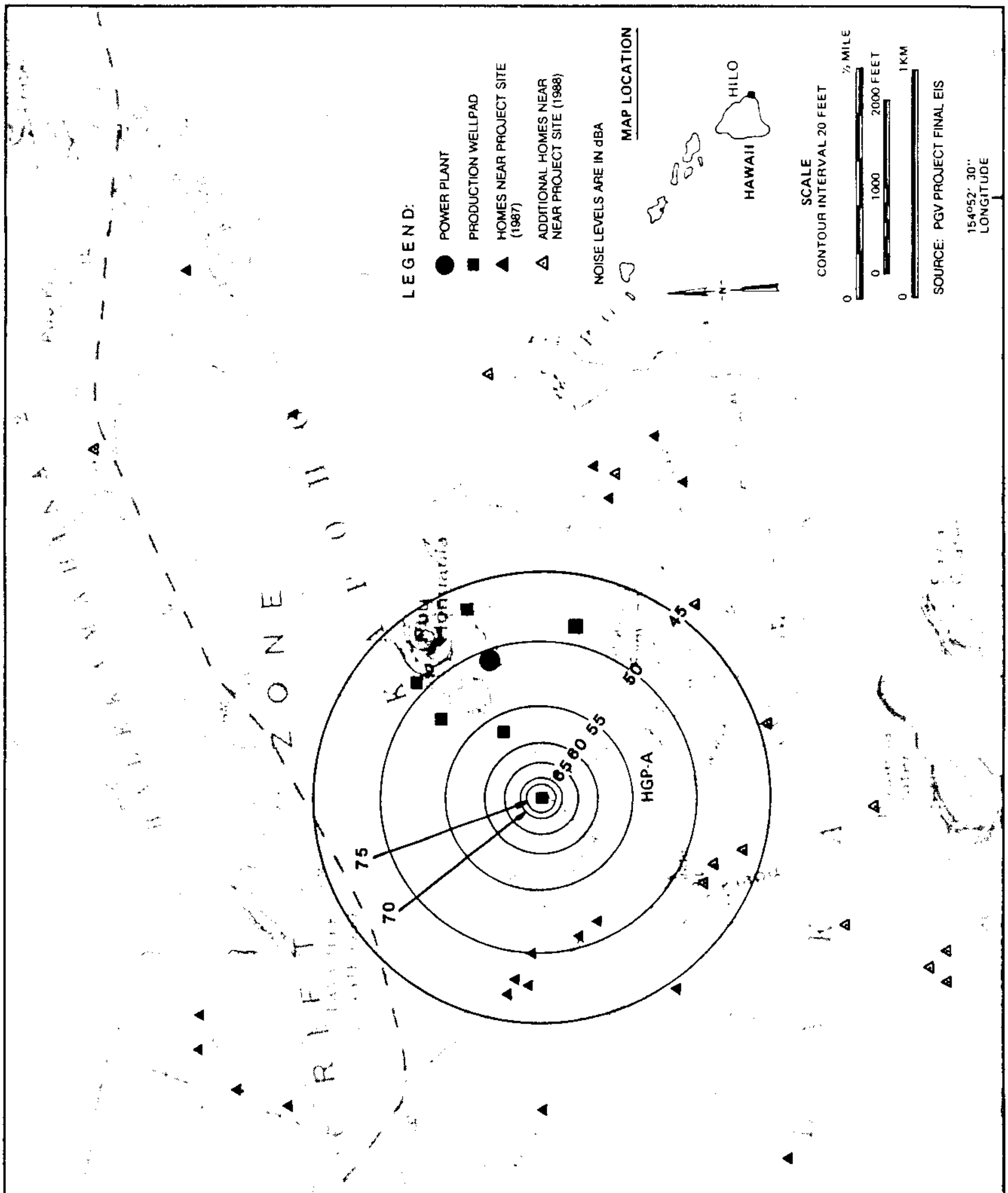


Figure 3-20. Predicted Contours of Well Drilling Noise at Wellpad E

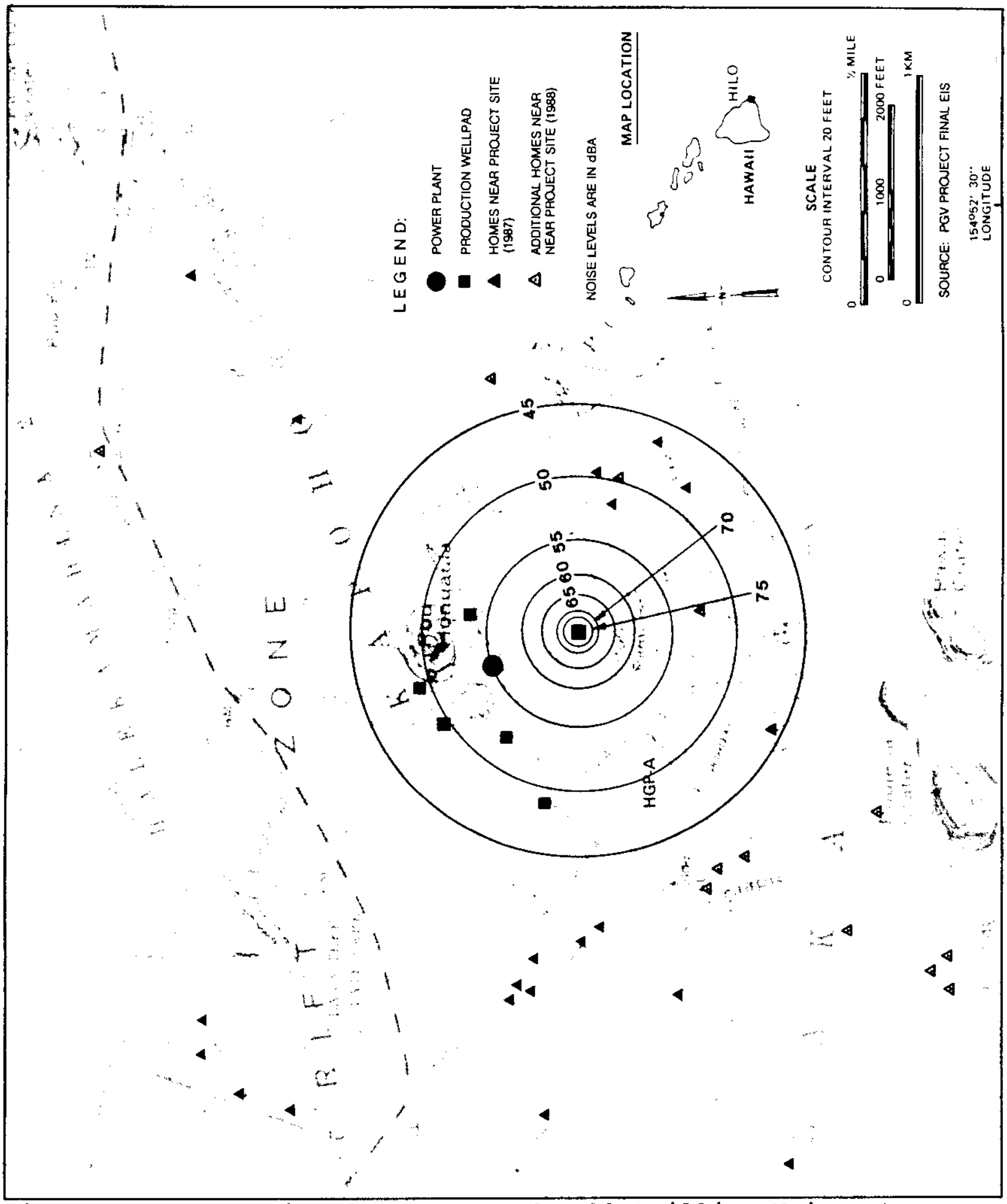


Figure 3-21. Predicted Contours of Well Drilling Noise at Wellpad F

Noise levels from well workover were predicted to increase to 48 dBA at Wellpad A and 54 dBA at Wellpad E for some Kapoho and Pohoiki-Bay Estates residents. The levels at the Lanipuna Garden residences were predicted to increase to 50 dBA from well workover at Wellpad B and 54 dBA at Wellpad F. All other well workover noise levels were expected to be approximately 45 dBA at nearby residences.

Initial, short-term, well venting to cleanout debris may produce noise levels as high as 125 dBA at 50 feet and 50 to 83 dBA at one mile. The wells will be tested to determine capacity and other characteristics after drilling and venting. Testing may initially require up to 10 days; however, it is the objective of the project to reduce this time to 24 to 48 hours of flow as more experience is gained on the wellfield. Testing may be performed continuously or intermittently for the required period. The PGV plant will utilize an effective rock muffler during flow testing to quiet the steam discharge to 55 dBA or less at the lease boundary.

The pipeline gathering system needs to be cleaned and pressure-tested prior to production. This process is referred to as pipeline cleanout and consists of intermittently venting steam from the well at high velocity to an opening in the pipeline where it is released, unmuffled, directly to the atmosphere. PGV will notify nearby communities of pipeline cleanout events. Cleanout normally occurs once for each section of pipeline and normally lasts about one half hour. Noise levels due to pipeline cleanout may be as low as those for steady drilling (75 dBA at 50 feet) or as high as those for unmuffled well venting which can reach 125 dBA at 50 feet, and between 50 to 83 dBA at 1 mile.

Table 3-17 shows the predicted octave band noise levels and resulting dBA values for the major noise sources in the power plant. Based on studies of similar OEC-unit projects, the air-coolers will produce the highest noise levels in the power plant area. The estimated values in Table 3-17 assume that individual steam turbines are enclosed or provided with noise controls of equivalent effectiveness, that appropriate noise control has been applied to the air cooling units and to the H_2S

Table 3-17. Noise Levels Used to Predict Power Plant Noise Emissions

	Sound Pressure Levels in dBA at 50 feet								
Item/Frequency (Hz)	63	125	250	500	1000	2000	4000	8000	dBA
Steam Turbine[a]	69	69	65	63	60	58	53	45	66
Air Cooler, per unit[b]	83	75	73	67	66	64	61	56	72
NCG compressor[c]	65	59	55	69	67	56	46	35	70
Flow noise in steam pipes[d]	51	52	50	51	48	46	43	33	53

[a]Extrapolated from Edison Electric Institute, 1978, with enclosures added.

[b]BBN report at Steamboat Springs, with additional silencing.

[c]Consultants in Engineering Acoustics.

[d]Includes acoustic insulation on steam piping. Not including valves.

Source: Consultants in Engineering Acoustics, 1988 abatement compressors, that some thermal/acoustical lagging has been applied to the piping and valves, as appropriate, and design flow velocities have been selected to avoid distinctive humming in pipelines. Some valve noise levels will exceed levels from piping, but these levels will attenuate to below plant noise levels at the receptors. The total noise power of the ten (10) air coolers will be 10 dBA above that of the individual unit. The combined noise levels from all sources of the proposed configuration is estimated at 83 dBA at 50 feet. These levels are expected to attenuate to 45 dBA within 0.6 mi (1 km) of the site, which is the level identified in the County geothermal noise level guidelines for nighttime noise levels in residential areas (see Figure 3-22).

Measures proposed to mitigate potential noise impacts from the project are discussed in Section 3.10.5.2.

3.10.Environmental Protection

As required by Rule 12.3(b)(2) part (J), this subsection provides "a written description of the measures proposed to be taken for protection of the environment, including, but not limited to, the prevention and/or control of:

(i) Fires.
(ii) Soil erosion.
(iii) Surface and groundwater contamination.
(iv) Damage to fish and wildlife or other natural resources.
(v) Air and noise emissions.
(vi) Hazards to public health and safety.
(vii) Socioeconomic impact(s), and
(viii) Impact(s) on public infrastructure and services."

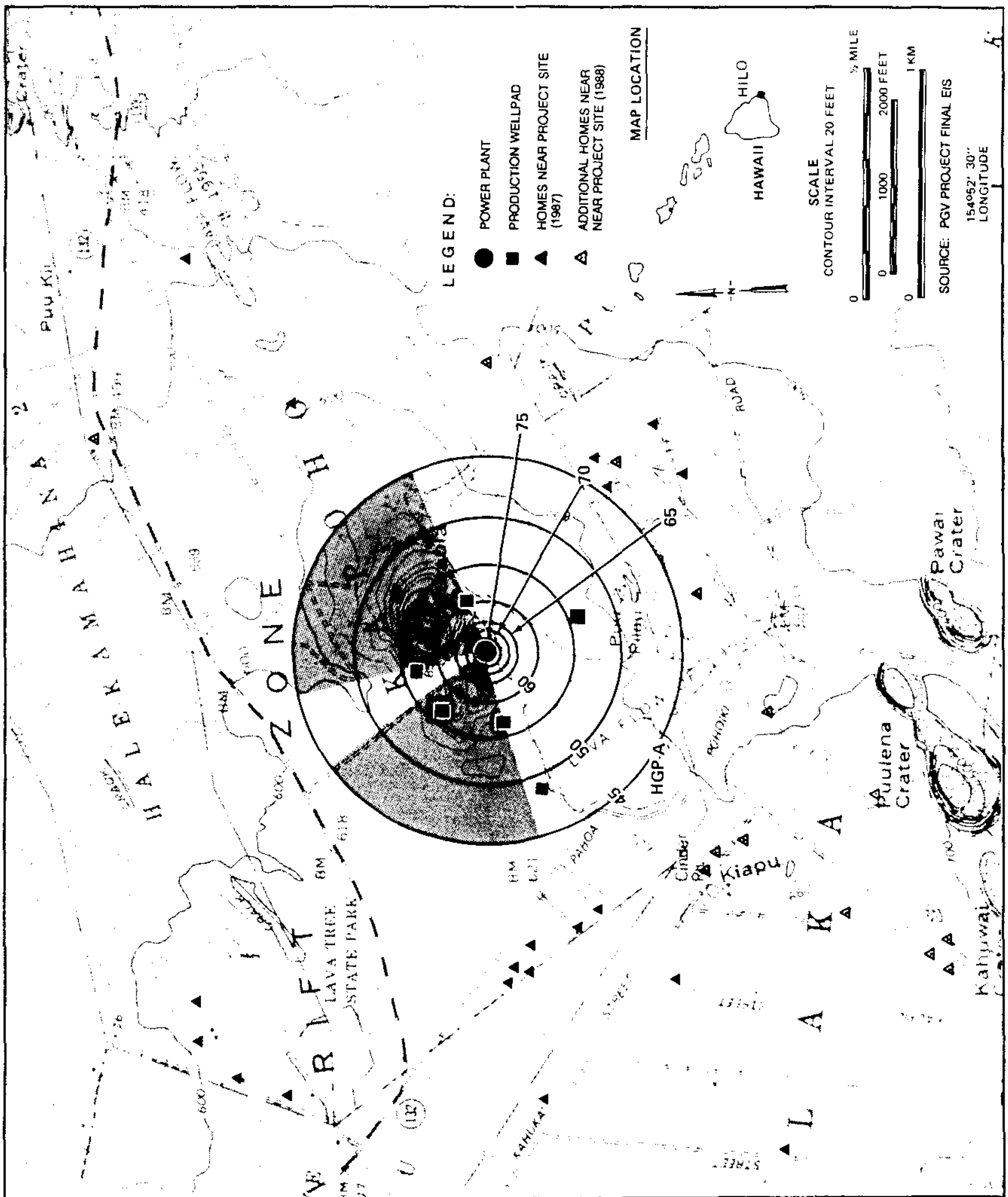


Figure 3-22. Predicted Contours of Noise from Normal Power Plant Operation

3.10.1. Fire Protection

The project will have a complete fire protection system, including a fire water storage tank, hydrants, and pumps. A sprinkler, CO_2 or Halon fire protection system will be installed in the control room, and an electrical fire protection system, and portable fire extinguishers, will be included. The fire protection system is described in more detail in Section 3.2.2.6.3.

Plant operating personnel will be trained in fire fighting techniques and will work closely with the Hawaii County Fire Department (Pahoa Fire Station) and Civil Defense personnel to coordinate emergency services.

3.10.2. Erosion Control

Grading of the relatively flat project areas is not expected to produce erosion problems. Approximately 75 percent of the project area is covered by soils, and these soils (Keaukaha, Opihikao, and Malama series) are classified by the Soil Conservation Service as having only a slight erosion potential. Table 3-18 gives the characteristics of these soils. The southwestern portion of the project area is covered by recent lava flows. The portions of the site covered by bare lava flows have virtually no erosion potential.

Erosion will be controlled by limiting construction vehicles to the areas planned for disturbance and by stabilizing cut and fill slopes according to Uniform Building Code requirements. The regrowth of natural vegetation in the disturbed soil areas will

Table 3-18. Soil Characteristics of Puna Geothermal Project Site

Parameter	Keaukaha Series	Opihikao Series	Malama
Depth	Thin, up to 8 inches	Thick	Thick, up to 12 inches
Description	Very dark brown, mucky, moderate-to-fine sub-angular blocky structure	Upper 3 inches very dark brown, mucky, friable, medium-to-fine subangular blocky structure	Upper 3 inches very dark brown, extremely stony muck
Permeability	High	High	High
Erosion Potential	Slight	Slight	Slight
Underlying Material	Pahoehoe	Pahoehoe	Aa

Source: Puna Geothermal Venture EIS

further stabilize soils.

3.10.3. Protection of Surface Waters and Groundwater

Measures to protect surface waters and groundwater have been incorporated into the project design, although there is no surface water in the project area and the groundwaters are influenced by leakage from the geothermal reservoir. No fresh water exists beneath or downgradient of the project site.

Drilling fluids (a nontoxic mixture of fresh water, clays, biodegradable detergents and special additives to control pH, viscosity, flocculation and foaming) will be discharged to unlined sumps under normal drilling operations. Although the drilling muds will settle to the bottom and form a lining, some liquids will percolate into the groundwater. In addition, some loss of drilling fluid in the subsurface during drilling is expected. Toxicity tests of drilling fluids previously placed in the Wellpad A sump show no EPA-defined toxicity levels. Arsenic, lead and mercury were among the metals analyzed for in these 1985 tests. Neither wellbore fluid losses while drilling or drilling sump residues are expected to approach toxic levels.

Geothermal brines and reacted abatement chemicals (soluble sulfides and hydrosulfides) will be discharged at the test site during well flow testing. The brines and liquids from the rock muffler will percolate into the shallow, geothermally-influenced groundwater. The volume of fluid is small relative to the large volumes of existing groundwater and to the rainfall recharge of the area. Testing of a 90,000 lb/hr well will produce approximately 45 gpm fluids during the 10-day testing period, while recharge from the rainfall on the 500-acre project area averages more than 1800 gpm year round.

As discussed in Section 3.2.3.5, dikes or berms will be constructed around the chemical storage tanks to contain any spills, and federal and state regulations will be followed for the handling and transportation of hazardous materials. Berms will also be constructed around the electrical transformers and the lube oil storage tanks.

All geothermal fluids that are withdrawn from the reservoir will, during normal operations, be injected back into the reservoir well below the shallow groundwater aquifer during normal operations. As required by drilling regulations, both the production and the injection wells will be cased and cemented, which will prevent the geothermal fluids from further mixing with the less saline waters in the upper aquifer. The injection wells will have an additional liner for corrosion control.

The closest sources of groundwater currently providing limited use is near the Kapoho Crater, three miles northeast of the power plant site and the Pahoa station, just less than three miles west of the site. Injection of the geothermal fluids is not expected to affect the waters there because the fluids will be injected below the caprock that seals the upper aquifer from the reservoir. In addition, the dominant dispersion pattern will direct groundwater toward the coast to the south.

3.10.4. Protection of Fish and Wildlife and Other Natural Resources

The biological and other natural resources of the Puna District will be protected by limiting the amount of habitat that will be disturbed by the project to a total of approximately 30 acres of scrub vegetation, fallow fields, and lava flows, five acres of which will only be disturbed temporarily. The project will avoid disturbance to significant biological resources and will control emissions and inject essentially all noncondensable gases and geothermal fluids into the geothermal reservoir.

Biological resources within one mile of the proposed power plant location have been surveyed. The survey recorded 240 plant species in the fallow fields, Metrosideros forests, and lava flows within the study area. Figure 3-23 is a vegetation map of the project area prepared by Char and Stemmermann in 1984. The

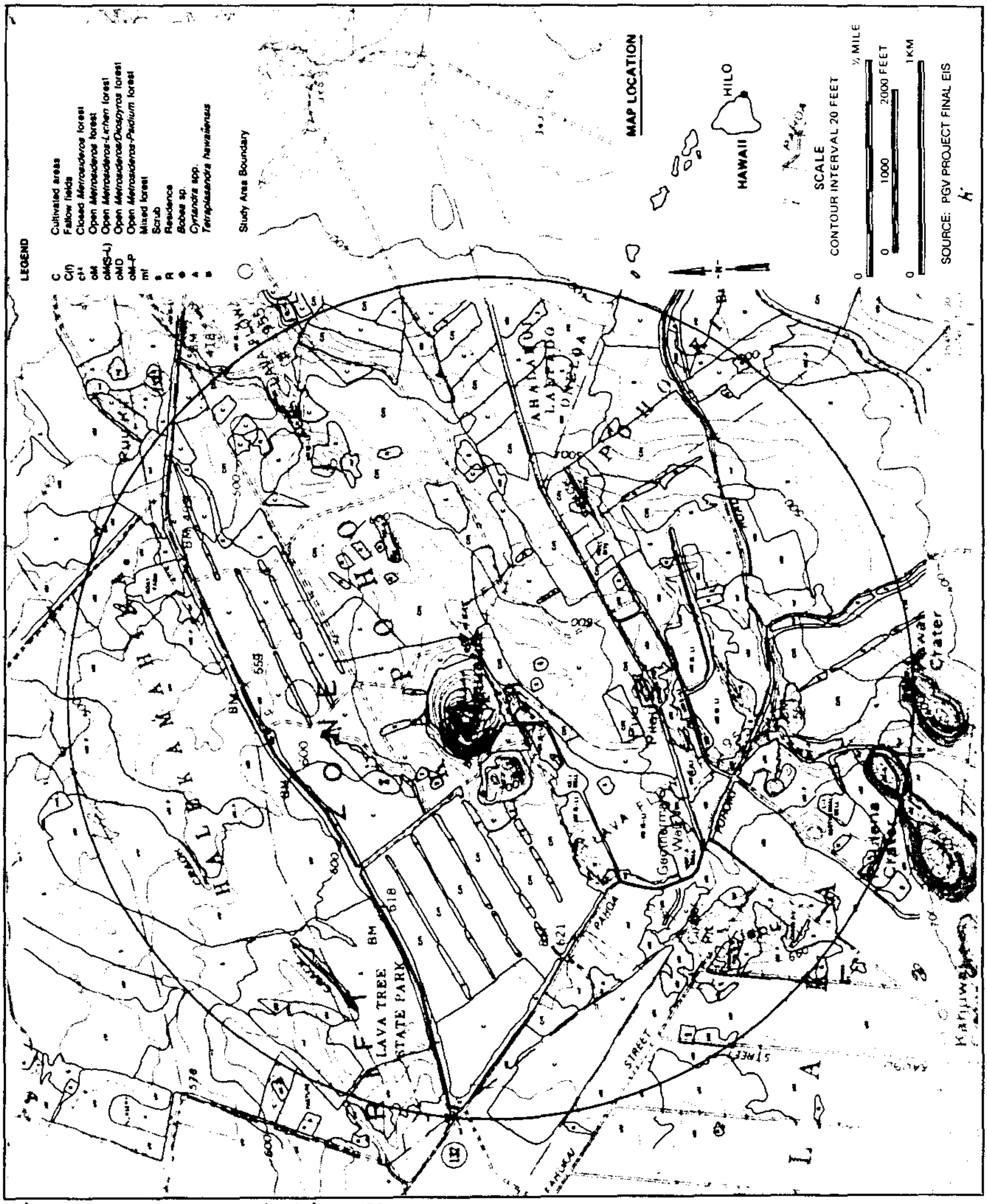


Figure 3-23. Vegetation Map

map shows that most of the areas planned for geothermal development are fallow fields, although Wellpads C and D and the temporary construction area were designated as cultivated in the 1984 survey. The power plant site and access road to Wellpad A will displace lands designated as cultivated and will extend into a portion of the open Metrosideros-Lichen forest.

No rare, endangered, or threatened plant species occur on the power plant or wellpad sites. One candidate endangered plant species (Tetraplasandra hawaiiensis) and three rare species of Cyrtantra and a Bobea species (possibly Bobea timonioides, a candidate endangered species) were identified within the 1-mile area.

Eleven bird species were observed within a 1-mile radius of Puu Honuaula during a 1984 study. Two of the species are native: the Hawaiian hawk and the lesser golden plover. The Hawaiian hawk is on the federal list of endangered species. Its breeding area encompasses most of the Island of Hawaii.

Four field studies of the Hawaiian hawk have been conducted between 1984 and 1986 in connection with the PGV geothermal project. The studies have shown that the hawks use the project area around Puu Honuaula for hunting. No nests have been found on Puu Honuaula. The nearest nest is located about one mile east of the project site.

The activities of the proposed project are not expected to adversely affect the Hawaiian hawk. The hawks are accustomed to human activities in the papaya fields, and use the area primarily for foraging. Even the loudest noises (well venting) will attenuate to 50 to 83 dBA at one mile and are unlikely to affect breeding of the hawk adversely (see Section 3.10.5.2). Under the proposed project design all geothermal wastes, emissions which could be harmful to wildlife will be injected, and the only emissions will be fugitives. Chemical treatment will be applied during well testing and to emergency steam releases to abate H_2S. H_2S emissions during normal operations would be less than 0.1 lb/hr, which would result in ambient levels well below injury level to sensitive plant and animal species.

3.10.5.Control of Air and Noise Emissions

As described in Section 3.2, procedures and techniques have been incorporated into the design of the PGV Project to control air and noise emissions during each stage of the project: site and pad construction, drilling, well testing, normal power plant operation, and emergency steam release during outages (steam stacking).

3.10.5.1.Control of Air Emissions

The following measures are proposed to protect the environment and public from potentially harmful air emissions from the PGV Project. These potential emissions include H_2S, particulate and trace elements in the steam; fugitive emissions of isopentane; criteria pollutants in the exhaust from construction and drilling equipment; and fugitive dust.

- During construction, conduct regular maintenance of construction equipment and drilling rig engines to prevent undue discharges of criteria pollutants (carbon monoxide, hydrocarbons, nitrogen oxides, sulfur dioxide, and total suspended particulate). Criteria pollutant emissions from these engines will not exceed the significant levels defined in the Hawaii Air Pollution Control Rules (Chapter 60, Title 11).

- Control fugitive dust from construction operations by sprinkling exposed soil in the construction area with water, as necessary.

- Install blowout prevention equipment (BOP) at each wellhead to prevent uncontrolled releases of geothermal steam at the wellhead.

- Employ mud drilling techniques to reduce H_2S emissions from most drilling operations to negligible levels. Inadvertent H_2S emissions during drilling with aerated water or mud will be less than 7.0 lb in ten minutes. Inadvertent releases of steam will be stopped (using BOP equipment if necessary) if they exceed 10 minutes.

- Vent the drilling fluids through a cyclone separator to control particulates during drilling.

- Ensure the integrity of the geothermal wells by designing wells and wellheads with conservative safety factors.

- Use conservative safety factors for design of process facilities and the related piping to prevent uncontrolled releases of air contaminants into the atmosphere.

- Limit time of well venting and cleanout (to approximately four hours duration) per well as much as possible and perform these operations only during proper meteorological conditions (winds ≥4 m/s) and with proper notification.

- Abate well testing emissions by (up to 95 percent) by routing the flow through the rock muffler at the wellpad and injecting water and NaOH, as needed.

- Use an H_2S abatement system which injects essentially all noncondensable gas back into the geothermal reservoir. This gas injection system has been demonstrated effective at the Coso geothermal field in California.

- Use air-cooled OEC units in place of water-cooled condensers and cooling towers to produce a closed-loop system that eliminates all but minor fugitive release of geothermal gases to the atmosphere.

- Design the injection system with spares for all major systems, including a spare pump, a spare compressor, and a spare injection well.

- Periodically inspect piping connections and welds to reduce fugitive emissions of H_2S and isopentane. Monitor pressure levels in working fluid cycle.

- Design the process plant equipment with automatic instrumentation and controls to minimize the possibility of a rupture disk event resulting from a process upset. Set rock muffler release valve at a lower trigger point than the rupture disk, so as to route overpressure steam to the abatement system in the mufflers.

- Use NaOH injection at the power plant rock muffler to control H_2S emissions by 96 percent during steam operations (state-of-the-art rock muffler design).

- Minimize the emissions from emergency steam releases by designing both steam turbine/OEC units with high reliability factors.

With these control measures, the total emission of H_2S will be less than 10 tons/year, which is the significance level for H_2S in the Department of Health (DOH) regulations. The proposed measures also meet the requirement of the DOH regulations which cover geothermal power plants and wells.

3.10.5.2.Control of Noise Levels

The following mitigation measures are proposed to mitigate potential noise impacts from the project. The most significant noise levels will be generated during short-term operations such as well venting, flow testing, and pipeline cleanout.

- Set construction equipment backup alarms at minimum legal limits.

- Reduce drill rig noise by using residential-grade mufflers, placing an acoustic enclosure around drill rig engines and other noisy mechanisms, and silencing engine radiator air inlets and outlets.

- Use silencers and/or enclosures on auxiliary equipment used during well drilling and workover operations (diesel generators, pumps, compressors, etc.).

- Employ steam vent muffling system when steam is encountered during well workover operations.

- Use rock mufflers to control noise during flow testing operations and emergency steam releases.

- Schedule especially noisy short-term operations, such as well venting and pipeline cleanout, for daylight hours only and notify the public prior to such operations.

- Acoustically insulate selected pipes and valves.

- Connect pressurized steam outlets to condensate piping and/or rock mufflers, where possible.

- Muffle or enclose individual steam turbine generators, or provide an equivalent level of noise control.

- Provide acoustic insulation, sound barriers, acoustically improved fan design, or other noise controls, as needed, on the air-cooled condensers.

- Schedule noisy maintenance activities for daylight hours only.

3.10.6. Protection of Public Health and Safety

The measures taken to control air emissions, reduce noise levels, and contain water effluents will also serve to protect public health and safety. The risks to public health and safety consist primarily of exposure to H_2S. The geothermal resource at Puna

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- Employ steam vent muffling system when steam is encountered during well workover operations.

- Use rock mufflers to control noise during flow testing operations and emergency steam releases.

- Schedule especially noisy short-term operations, such as well venting and pipeline cleanout, for daylight hours only and notify the public prior to such operations.

- Acoustically insulate selected pipes and valves.

- Connect pressurized steam outlets to condensate piping and/or rock mufflers, where possible.

- Muffle or enclose individual steam turbine generators, or provide an equivalent level of noise control.

- Provide acoustic insulation, sound barriers, acoustically improved fan design, or other noise controls, as needed, on the air-cooled condensers.

- Schedule noisy maintenance activities for daylight hours only.

3.10.6. Protection of Public Health and Safety

The measures taken to control air emissions, reduce noise levels, and contain water effluents will also serve to protect public health and safety. The risks to public health and safety consist primarily of exposure to H_2S. The geothermal resource at Puna has higher H_2S concentrations and lower arsenic, boron, mercury, and radon-222 concentrations than other geothermal resources developed on the mainland (Geysers, Imperial Valley, Coso, Nevada, and Utah). The proposed design with its closed-loop configuration of steam turbines/air-cooled OEC binary units and gas injection system will minimize public exposure to H_2S and the other elements in the geothermal fluids. The geothermal fluids and gases will be isolated from the atmosphere and will only be released as fugitives or in the event failure of multiple units in this configuration. The maximum predicted ambient levels of H_2S are below the proposed State of Hawaii standard of 0.10 ppmv, which is set 100 times lower than the occupational standard.

Other potential health and safety concerns are exposure to elevated noise levels (occupational exposure), construction accidents with heavy equipment, exposure to hazardous chemicals, traffic accidents, well blowouts, and pipeline ruptures. The potential risks associated with these hazards are comparable to and, in some cases, less than other industrial projects.

In addition to the measures taken to control air emissions (see Section 3.10.5.1), the following design measures are proposed to protect public health and safety.

- Design wellfield program to prevent blowouts (see Section 3.2.1.3 and Appendix B for details on blowout prevention equipment).

- Design pipelines in accordance with applicable ANSI and Hawaii State pipeline safety requirements.

- Implement noise suppression measures in all phases of project design and operation (see Section 3.10.5.2).

- Secure the project area with a chain link fence around wellpads and power plant site and limit public access.

- Require training of personnel in the areas of safety and emergency procedures, such as the proper shutdown of well equipment during an emergency.

- Employ hand-held H_2S monitors for employees throughout the plant during well venting, flow testing, pipeline cleanout and maintenance activities in confined space to promptly detect any H_2S exposure. Install H_2S alarms in noncondensable gas compression areas and other areas where H_2S may accumulate.

- Adhere strictly to applicable hazardous materials storage and transportation regulations. Inform all employees of the hazards of each compound and the appropriate emergency procedures in the event of an accidental contamination.

- Schedule deliveries and truck traffic to avoid peak traffic periods and install turnout lanes on the main access road.

- Work with Civil Defense in the development of the emergency response plans.

3.10.7. Prevention of Adverse Socioeconomic Impacts

The development of the PGV facility will result in a number of positive economic and social impacts. These impacts include jobs for local residents, increased economic activity from capital expenditures in the county, increased state and county revenues from taxes, royalties, and permit fees, and increased energy self-sufficiency.

The PGV Geothermal Project will provide both the State and the Island of Hawaii with a number of beneficial aspects and assists in meeting a number of goals. The project is anticipated to:

- Decrease dependence upon imported petroleum products.
- Diversify Hawaii's economic base.
- Provide increased employment opportunities and personal income.
- Increase public revenues and capital expenditures.
- Provide a dependable and efficient source of energy.
- Develop an alternate, renewable energy source which is indigenous to the Island.
- Further the State program to develop additional information on the commercialization of geothermal energy.

The Puna District, with a 1984 population of 16,530, is the third most populous of the Island Of Hawaii's nine districts. During the 1970s the Puna District experienced a 128 percent population growth which shifted the ethnic composition of the area from largely Japanese to largely Caucasian. During the same period, the proportion of Puna's population consisting of native Hawaiians increased from 9 percent to 15 percent. Many of the immigrants to the area were from the mainland, either retirees or participants in subsistence economies, and were attracted to the area because of its isolated, natural environment.

Although the economy of the island as a whole has shifted from agriculture to tourism over the past several decades, the economy of the Puna district is largely unaffected by tourism. A 1982 survey of 778 Puna households showed that 31 percent were retired or not working, 20 percent working in agriculture, 12 percent in construction, 8 percent in government, and 1 percent in the geothermal industry. Puna has been a major sugar producing area, but production has stopped since the Puna Sugar Company ceased operations in 1984. The median family income in lower Puna where the project is located is 72 percent of the island-wide level, and the area has a higher proportion of families qualifying for poverty status than the rest of the island.

The housing supply in Puna increased by 79 percent in the 1970s, with most new housing stock generated through custom home construction in land subdivisions. The median value of owner-occupied housing in Puna is significantly lower than for the island as a whole.

Most of the positive socioeconomic impacts are associated with the direct and indirect effects of the estimated 23 construction and 19 operations and maintenance jobs at the proposed project that will be filled by local employees. Peak construction employment is estimated to be as high as 100 people. Construction of the project will generate a total annual increase in personal income of more than $16 million, and that annual operation will produce another $1.8 million. The proposed project will also increase county revenues through property taxes, permit fees, and other fees collected through increased economic activity.

Additional employment may be generated by potential spin-off activity such as use of geothermal heat for papaya drying or industry attracted to other areas of the island by the existence of reliable electrical energy. Spin-off activities are not an automatic consequence of the proposed action, and future industries would have to be permitted on a case-by-case basis. The socioeconomic effects of the project were perceived as positive by most of the region's population but some perceived the project as disruptive to the traditional rural atmosphere. Surveys indicate support of two-thirds of the population for geothermal development on the scale of the proposed project. About 17 percent of respondents opposed the project. This opposition may decline if the proposed project operates as unobtrusively as planned.

The measures proposed to avoid adverse socioeconomic effects are the same as those designed to protect the other aspects of the environment: control of air emissions, noise levels, and other impacts so that they will not intrude upon the rural environment outside the project boundaries. Additionally, state and county government planners can help allay community fears about the PGV Project by providing local forums for discussion of geothermal development.

The only potential adverse socioeconomic impacts of the project will be visual. Visual analysis indicates most views of the project area will be screened by existing vegetation or by Puu Honuaula. The project will be visible from portions of Highway 137, Pahoa-Pohoiki Road, and Leilani Avenue; however, these views will be from at least 0.5 miles distance, and visibility impacts will be mitigated by the measures described in Sections 3.3.1 and 3.3.2.

3.10.8. Prevention of Adverse Impacts on Infrastructure and Services

3.10.8.1. Traffic

Traffic through Pahoa will increase slightly during construction of the project. Approximately 35 vehicle round trips per day are expected during the wellfield and power plant construction. Traffic during normal power plant operation will drop to about 10 to 18 vehicle trips per day. These added vehicle trips amount to a less than a one percent increase over existing traffic levels at the intersection of Highways 130 and 132, based upon the existing traffic levels of 2000 to 3600 vehicles per day at this intersection. The increase should not cause a significant impact on traffic in the project area.

PGV plans to use Kapoho Road (Highway 132) rather than the existing access road (Pahoa-Pohoiki Road) as the primary access to the site because it has fewer curves. An entrance road will be constructed to the project site. A right-turn lane from Kapoho Road into the project area will be provided for traffic coming from the west. This right-turn lane will reduce traffic congestion associated with vehicles (especially construction-related vehicles) turning into the project site.

3.10.8.2. Utilities

Telephone service is provided by the Hawaii Telephone Company and expansion is provided as demand requires. During construction, electrical power will be provided by HELCO. A 34.5 kV overhead electrical transmission line currently extends along the Pahoa-Pohoiki road to the HGP-A Site to share poles with the telephone system.

During operation, onsite power requirements will normally be met using power generated by the plant itself. A diesel generator unit will be available as an emergency backup if the system power fails (see Section 3.2.2.4).

3.10.8.3. Water Supply and Distribution

The public water supply and distribution system is operated and maintained by the County Department of Water Supply. There are four major public water systems in the Puna District, one of which has been extended beyond the HGP-A project site from a well located above Pahoa. A water line supplies potable water from the county water main.

Up to 30,000 gallons of water per day will be needed during the drilling for makeup to replace lost circulation fluids. PGV plans to purchase this water from the county unless it develops its own water supply. For supplemental injection water needs see Section 3.2.2.6.4.

Service water requirements for the PGV facility are estimated at approximately 1000 gallons per day from the public water system. Service water is required for drinking water, sanitation, occupational safety (i.e., emergency showers and eyewash stations), and chemical mixing and makeup water.

For general plant purposes, there will be a separate system utilizing condensate water. If additional water is needed, rain catchment water, piped-in County water, and trucked-in water can be used.

Initial filling of the fire water tank will be from the county water system. Make-up will be from the condensate system.

3.10.8.4.Sewage Disposal System

There will be no impact on public sewage facilities from the PGV Project. It is estimated that the proposed project would generate an average of less than 200 gallons of domestic wastewater per day. Current plans are to dispose of domestic wastewater at onsite in cesspools. These cesspools are expected to perform satisfactorily due to the highly porous nature of the soils and underlying rock and their successful usage elsewhere in Puna. Portable toilets may also be used during peak periods. No public drinking water sources would be affected by this disposal system.

site in Leilani Estates. Six residences are within a half-mile of the site; another 24 within a mile. The proposed project will occupy about 5 percent of the 500 acres leased by the project. The remaining acreage will provide a buffer zone between the project and the residences. The presence of residential development relatively close to the site has prompted the PGV Project to employ the most effective measures to control air and noise emissions.

With the proposed project design, the geothermal fluids, which contain H_2S, will not come in contact with the atmosphere during normal operation. During some outages, steam will be released through the rock mufflers, but this steam will be treated with state-of-the-art abatement systems to control emissions by 96 percent. At this level of control, the ambient concentrations of H_2S in the residential areas will be well below the levels known to cause health effects.

A study of the impact of the HGP-A facility on housing values in the vicinity of the site found that the odor of H_2S emissions from the HGP-A facility could decrease housing values of residences within 0.5 miles of the power plant site by as much as 50 to 70 percent. The proposed project, with much more effective H_2S control technologies than HGP-A, is not expected to produce this kind of decrease in housing values.

Similarly, the noise levels will be reduced so that the attenuated levels at the nearest residences will be lower than those levels specified in the guidelines developed by the County of Hawaii Planning Department. Noise from the existing HGP-A Project was not audible during the site surveys. PGV will monitor noise levels and ambient concentrations of H_2S, to verify the predicted impacts of the proposed project (see Section 3.12). This monitoring program will also provide reassurance to the community that there are no adverse health or environmental effects.

The implementation of effective environmental controls is expected to preclude any adverse socioeconomic effects on the surrounding residences. Without unpleasant odors or noise levels and with proper vegetative screening and a sufficient buffer zone between the project and the residential areas, there is no physical basis for the project affecting property values.

Despite these measures, some unanticipated effects may occur or residents may feel that additional mitigation is required to offset unanticipated project effects. PGV has participated in a number of local community groups, which are intended to provide a forum for resolution of issues and discussion of measures to reconcile public impacts. Some of these political and community groups include:

Puna Community Council
Leilani Community Association
Nanawale Community Association
Mayor's Geothermal Advisory Commission
Big Island Business Council
Hawaii Island Economic Development Board
Hawaii Island Chamber of Commerce

PGV will continue to work with these organizations and with the Planning Commission and Department to develop additional measures, if needed, to mitigate or reconcile public impacts.

Similarly, the project will have its own roads, sewage system, water collection system, fire protection system, and drainage systems, although it will use water from the Pahoa District (see Section 3.10.8). These systems will prevent adverse impacts on public agencies providing infrastructure support in areas such as roads, sewers, water, drainage, related services and police and fire protection. If unanticipated effects occur during the construction or operation of the project, PGV will work directly with the affected agency and the Planning Department to develop measures to relieve the unforseen burden on local agencies.

3.12.Monitoring Plans

This subsection explains "preliminary provisions and/or plans for the monitoring of environmental effects such as noise and air and water quality during each proposed phase of the project (exploration, development and production) demonstrating how the applicant intends to comply with this rule, the rules of the State's Department of Health, and the rules of the State Board of Land and Natural Resources" as required by Rule 12.3(b)(2) part (L).

3.12.1.Meteorological and Air Quality Monitoring

The meteorological monitoring stations at the "Woods" Site and at the plant site will be kept in continuous operation, and additional meteorological and air quality monitoring will be performed to ensure that all design and environmental criteria are met. Meteorological monitoring at the "Woods" Site include wind speed, wind direction, wind direction fluctuation (sigma theta), temperature, relative humidity, rainfall, and solar radiation. Meteorological monitoring at the plant site includes wind speed, wind direction, temperature, relative humidity, and rainfall.

Continuous ambient measurements of H_2S will likely be conducted at three sites: "Schroeder", "Gilman", and a new site located near the residences on Kaipu. H_2S levels will be monitored throughout the construction, operation, and decommissioning phases of the project. During well drilling and plant operations, the air will be monitored in strategic locations. Permanent H_2S monitors and emergency air units will be located in strategic places. Hand-held H_2S monitors will also be used extensively throughout the plant for detection of H_2S exposures in those areas not having permanent detectors, especially in confined spaces.

Because the proposed PGV Project design eliminates the cooling tower and the cooling tower drift, which was identified as the primary source of arsenic from the previously proposed PGV Project, PGV does not plan to conduct the previously proposed arsenic monitoring studies. All of the arsenic, radon, mercury, lead, and other trace elements in the geothermal fluids will be contained in the brine, condensate, and gases that will be injected back into the geothermal reservoir. There will be no occupational exposure to these elements during normal operation of the project, and the only occasions for exposure will be the infrequent periods of emergency steam release and well testing and turbine maintenance. Brief periods of exposure to low concentrations of these elements do not require occupational monitoring studies. Similarly, there will be no radon releases from the proposed design, and PGV does not plan to monitor ambient levels of radon near the site.

3.12.2.Noise Monitoring

PGV will perform a 24-hour noise monitoring survey after start-up of the power plant to verify the noise specifications of equipment and a noise survey to ascertain the impacts of operational L_{90} and L_{eq} noise levels on residential areas and compliance with County guidelines. Noise monitoring will also be conducted if requested by the Planning Department in response to public complaints. Public notification will be provided for one-time events which may cause high noise impacts, such as well venting or pipeline cleanout.

3.12.3.Biological Monitoring

PGV does not intend to continue biological monitoring of the Hawaiian hawk, because changes in the project design eliminate the major source of regular emissions, and, consequently, the potential for impacts on the Hawaiian hawk and any rare native plants from cooling tower emissions is eliminated. Although the noise impacts will be similar to those described, no adverse impacts on the Hawaiian hawk are anticipated from even the loudest noise produced by the PGV facility.

3.12.4.Compliance with Regulations

The planned monitoring will assure that the project is in compliance with the following regulations:

- County of Hawaii Planning Commission's Rule 12 (Geothermal Resource Permits).

- DOH's Ambient Air Quality Standards (Title 11, Chapter 59), Air Pollution Control regulations (Title 11, Chapter 60), and Underground Injection Control regulations (Title 11, Chapter 23).

- DLNR Geothermal Plan of Operation rules (Title 13, Chapter 183, Subchapter 7), Well Drilling rules (Title 13, Chapter 183, Subchapter 8), Well Modification for Injection requirements (Title 13, Chapter 183, Subchapters 8 and 9), and Well Abandonment regulations (Title 13, Chapter 183, Subchapters 8 and 11).

Necessary permits will be obtained from the authorizing governmental agency. Permit applications will detail how the PGV operations will comply with the applicable requirements.

3.13. Emergency Preparedness Plans

This subsection provides "a preliminary plan of action for emergency situations which may threaten the health, safety, and welfare of employees and other persons in the vicinity of the proposed project site including, but not limited to, procedures to facilitate coordination with appropriate Federal, State and County officials and the evacuation of affected individuals," as required by Rule 12.3(b)(2) part (M).

The PGV Project submitted an emergency preparedness plan for well drilling and testing of the existing wells and a plan to cover the current period when the wells are closed down (shut in) and unattended. These plans have been approved by the County Civil Defense Director and are in effect. Prior to the beginning of construction, these emergency preparedness plans will be combined and expanded to cover the construction and operational phase of the project. An outline of the information recommended for the construction and operational phase is presented in Appendix D. During operation the emergency preparedness plan will be reviewed annually and updated to reflect current contact telephone numbers and safety requirements.

The plan will describe the proposed facility and its operation, identifying areas of potential hazard such as storage of flammable materials (lube oil, isopentane), presence of potentially hazardous substances (H_2S and NaOH), and high-pressure piping. The plan will describe coordination agreements with outside agencies and define the division of responsibility expected between the agencies and the project. Onsite chains of command and levels of responsibility in emergency situations will be included in the emergency preparedness plan.

The operation plan will be divided into subsections according to the potential hazards (well blowout, chemical spills, H_2S hazards, pipeline rupture, fires, contaminated soils, etc.). For each subsection, the plan will identify technical data on the nature of the hazards (for example, the concentrations of H_2S in the various areas and the hazard associated with these concentrations, the corrosive characteristics of the abatement chemicals) and describe the warning systems (such as H_2S detectors used to alert personnel of the hazard). Each subsection will also define the location and use of equipment used to control the hazard (fire protection equipment, isolation valves). It will identify the personnel trained in the use of that equipment and define the authorities which must be notified if the hazard occurs. Additional subsections will deal with natural hazards such as lava flows, earthquakes, and storms, and identify coordination agreements and expected warning times. A summary checklist will be provided that identifies the emergency, describes control options, and defines when to evacuate and when to notify outside services and agencies.

The plan will identify the location and capabilities of available medical facilities and will describe plans for transporting injured personnel. Evacuation plans and alternate routes, including meeting points, will be included in the plan. The plan will identify those situations requiring media and/or public notification and list personnel authorized to make statements to the media and/or the public.

Training requirements will be included in the plan, including procedures for emergency shutdown, handling of emergency equipment, spill prevention, first air and rescue, fire fighting procedures, and evacuation training. The plan will also include reporting and recordkeeping requirements.

3.14. Schedule

This subsection provides a "preliminary timetable(s) and/or schedule(s) for each proposed phase of the project" as required by Rule 12.3(b)(2) part (N).

The current development schedule for the PGV Project calls for the commencement of the development of the geothermal wellfield and the construction of the power plant as soon as all the necessary permits are obtained and the contract with HELCO is finalized. Accordingly, PGV assumes that the wellfield development and construction of the power plant will start during the second half of 1989. The wellfield development and the power plant construction will continue uninterrupted through to the end of 1990, when commercial operation of the full 25 MW project is scheduled to commence (see Figure 3-24). Permit acquisition and project engineering are both currently in progress, and equipment fabrication is scheduled to begin by mid-1989, as soon as all the permits are obtained and the contract with HELCO is finalized.

The final timing of commercial operations will depend, in part, on the results of the capacity contract and transmission line negotiations now being concluded between PGV and HELCO, and the completion of the permitting process. However, the current schedule anticipates that commercial operations will commenced in stages, as requested by HELCO, which is made possible by the modular nature of the power plant design. As currently envisioned, the schedule calls for the first phase of the project, generating 7.5 MW, to be ready by early 1990. At this phase, all the power generating units will be OEC binary units, which can be manufactured in a shorter time than the steam turbines. The second phase, generating up to 20 MW, will consist of all the OEC units and, if available, a few steam turbines. The final phase of the project, generating the total 25 MW (net), would commence commercial operation by the end of 1990. Depending on the transmission line and contract negotiations with HELCO and the date that all permits are obtained, a possible alternative schedule divides the project into only two phases; 12.5 MW by mid-1990, and completion to 25 MW by the end of 1990. In any case, the drilling of the wells and construction of the power plant is scheduled to start as soon as possible and will continue uninterrupted through to the end of 1990 when full commercial operation commences.

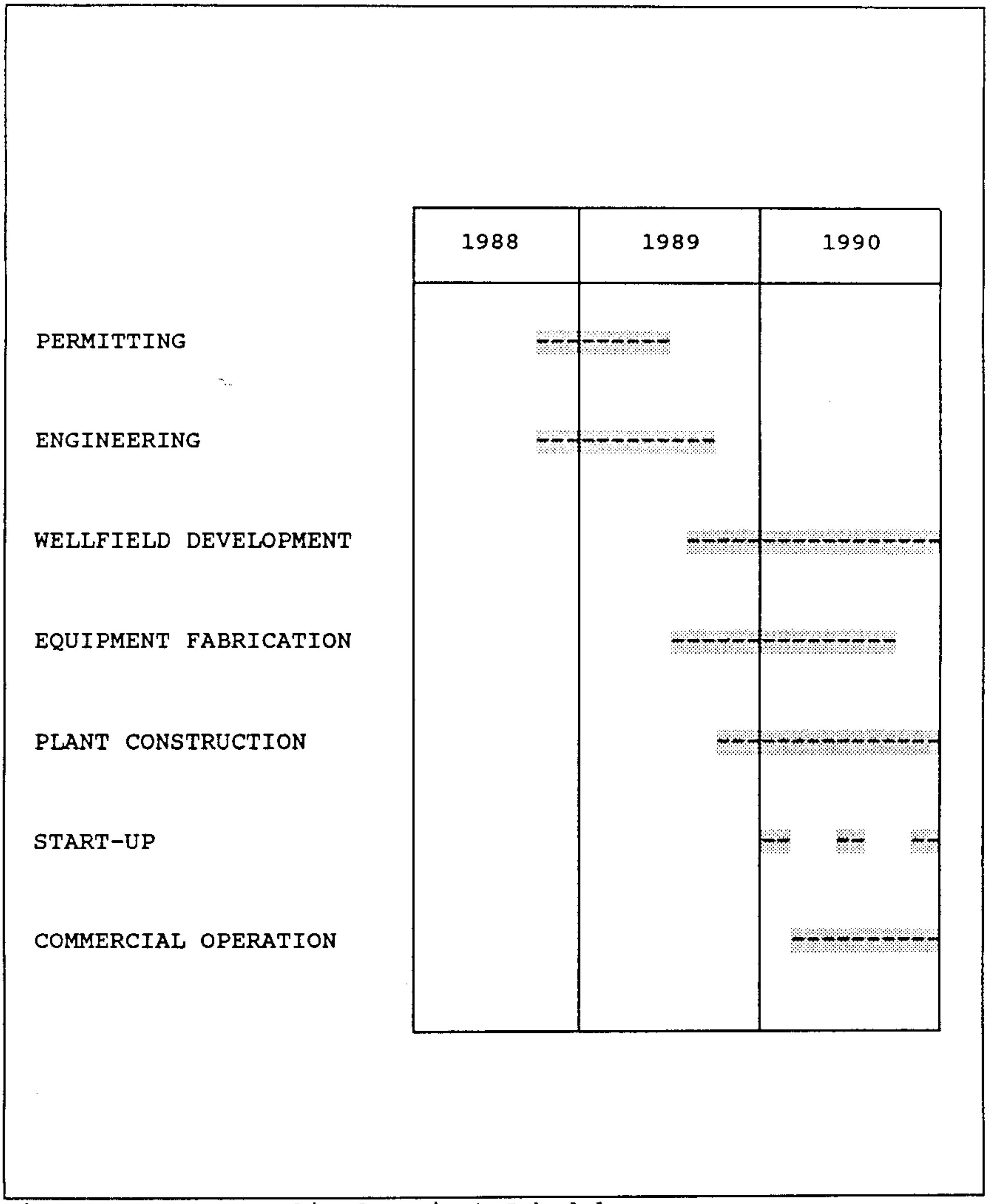


Figure 3-24. Generalized Project Schedule

The operational life of the facility is estimated to be 35 years, after which the plant and wellfield will be decommissioned (see Section 3.2.7).

3.15. Progress Reports

This subsection includes a discussion "method(s) of presenting timely progress reports to the Planning Commission" as required by Rule 12.3(b)(2) part (O).

Written progress reports will be submitted to the Planning Commission as required.

3.16. Cultural Resources

This subsection includes "other pertinent information or data such as an archaeological survey which the Planning Director may require to support the application for the utilization of geothermal resources and the protection of the environment," as Required by Rule 12.3(b)(2) part (P).

The PGV Project should not impact on the cultural and historical resources of the Puna area. The district did not play an important political role in the history of the island and was typically controlled by chiefs of the adjacent districts, Hilo or Kau. The district was a traditional religious center with some of the first heiau, places of worship, built in the Kapoho area, several miles from the site. Most of the archaeological sites in the area have been at Kapoho or on the coast.

At the request of PGV, the Department of Anthropology of the Bernice Pauahi Bishop Museum performed an archeological reconnaissance survey of specified lands (Tax Map Key 1-4-01:1, 1-4-01:2, and 1-4-01:19) in the Kapoho area in January 1984. The purpose of the survey was to determine the presence or absence and general nature of any archeological resources evident on the surface of the project area. A copy of the study can be reviewed by the public at the Historic Sites Section of the Department of Land and Natural Resources (DLNR). The DLNR reviewed the study and concluded that the project will not have an effect on historic sites.

The survey included a systematic walk-through of the site area. The area within a 1-mile radius of the immediate survey area was also investigated on a less intensive basis. No archeological sites were located during the reconnaissance survey.

No further archeological work is planned prior to development because of the lack of surface remains and the highly unlikely event that subsurface remains will be encountered during the construction phase of this project. However, if construction activities expose any cultural remains, PGV will consult with the State Historic Preservation Office, and a qualified archeologist will be contracted to monitor further work and implement appropriate mitigation procedures.

The proposed geothermal wells and power plant are located in Kilauea Volcano's East Rift Zone, part of Pele's traditional home. Some worshippers of the goddess Pele believe that withdrawing steam from the volcano would desecrate her body. Consequently, an appeal was filed on decisions by the State Board of Land and Natural Resources (BLNR) to allow geothermal development in approximately 9,000 acres of the Wao Kele O Puna forest area, about 8 miles up-rift from the project site. The challenge was brought on the grounds that the development would interfere with the plaintiff's constitutional rights to practice their religion (Pele worship). However, the Hawaii Supreme Court subsequently ruled that the plaintiffs had not shown that geothermal development would infringe on their religious practices. The Court therefore denied the appeal and upheld the BLNR decision allowing geothermal development. Subsequently, the Pele Defense Fund asked the U.S. Supreme Court to consider the same case, but the Court returned the request without comment, indicating it would not hear the case and letting the state court ruling stand.

Although some native Hawaiians have opposed geothermal development on religious grounds, other Hawaiians have accepted it and found the use of geothermal energy consistent with traditional approaches to the utilization of natural resources. The proposed closed binary cycle, which returns all geothermal fluids to the reservoir, is more in keeping with Pele's admonition not to remove rocks and volcanic material from Hawaii. PGV respects Hawaiian religious beliefs, and its operations will not interfere with local religious practices. Hawaii religious figures have previously blessed the drilling of wells and the installation of major pieces of equipment at Puna, and PGV plans to continue this practice.

APPENDIX A - LIST OF ABBREVIATIONS

AAQS	Ambient Air Quality Standard
ACGIH	American Conference of Governmental Industrial Hygienists
AMSL	Above Mean Sea Level
ANSI	American National Standards Institute
Ar	Argon
As	Arsenic
BACT	Best Available Control Technology
B	Boron
BLNR	Board of Land and Natural Resources, State of Hawaii
BOP	Blowout Prevention Equipment
Br	Bromide
Ca	Calcium
CFR	Code of Federal Regulations
CH_4	Methane
C_2H_6	Ethane
Cl	Chloride
CO	Carbon Monoxide
CO_2	Carbon Dioxide
CO_3	Carbonate
dB	Decibels
dBA	Decibel, A-weighted
DBED	Department of Business and Economic Development, State of Hawaii
DLNR	Department of Land and Natural Resources, State of Hawaii
DOH	Department of Health, State of Hawaii

APPENDIX A
(continued)

List of Abbreviations

DOSH	Department of Occupational Safety and Health. State of Hawaii
DPED	Department of Planning and Economic Development
EIS	Environmental Impact Statement
EPC	Estimated Permissible Concentrations
ERZ	East Rift Zone
F	Fluoride
°F	Degrees Fahrenheit
Fe	Iron
gpm	Gallons per minute
GLC	Ground Level Concentration
H_2	Hydrogen
HCO_3	Bicarbonate
HELCO	Hawaii Electric Light Company
He	Helium
Hg	Mercury
HGP-A	Hawaii Geothermal Project - Abbott
HRS	Hawaii Revised Statutes
H_2S	Hydrogen Sulfide
HVAC	Heating, Ventilating and Air Conditioning
Hz	Hertz, Equivalent to Cycles per Second
I	Iodide
KLP	Kapoho Land Partnership
KS	Kapoho State (Wells)
kV	Kilovolt
lb/hr	Pounds per Hour
L_{90}	Sound Pressure Level Exceeded 90% of the Time During a Given Time Period

APPENDIX A
(continued)

List of Abbreviations

L_{eq}	Equivalent Sound Level During a Given Time Period
LERZ	Lower East Rift Zone
Li	Lithium
Lp	Sound Pressure Levels
M	Meters
Mg	Magnesium
mg	Milligrams
mg/1	Milligrams per Liter
mg/m^3	Milligrams per cubic meter
Mi	Mile
Mn	Manganese
mph	Miles per Hour
Ms	Modified Mercalli Scale
MSL	Mean Sea Level
MW	Megawatt
MWH	Megawatt Hour (Power)
N_2	Nitrogen
NAAQS	National Ambient Air Quality Standards
Na	Sodium
NaOH	Sodium Hydroxide
NH_3	Ammonia
NCG	Noncondensable Gases
NO_x	Oxides of Nitrogen
NWS	National Weather Service
O&M	Operation and Maintenance
OSHA	Occupational Safety and Health Administration
pCi/1	Picocuries per liter
PE	Precipitation Evaporation

APPENDIX A
(continued)

List of Abbreviations

PEL	Permissible Exposure Limit
PGV	Puna Geothermal Venture
ppm	Parts per Million
ppmv	Parts per Million-Volume
ppmw	Parts per Million-Weight
psi	Pounds per Square Inch
psia	Pounds per Square Inch-Absolute
psig	Pounds per Square Inch-Gauge
S	Elemental Sulfur
SiO_2	Silica
SO_2	Sulfur Dioxide
SO_4	Sulfate
STEL	Short-Term Exposure Limit
TDS	Total Dissolved Solids
TLV	Threshold Limit Value
TPC	Thermal Power Company
TSP	Total Suspended Particulates (Air)
TSS	Total Suspended Solids (Water)
μg	Micrograms
$\mu g/m^3$	Micrograms per Cubic Meter
UIC	Underground Injection Control
USDW	Underground Source of Drinking Water
yr	Year

APPENDIX B - WELL DRILLING AND COMPLETION PROGRAM

1. Well Design

   The planned production well design is shown in Figure B-1.

2. Drilling Program

   2.1 Prepare 10 ft. x 10 ft. x 8 ft. deep cement-rebar wellhead cellar on existing location. Set 30-inch conductor pipe through cellar floor.

   2.2 Move in Drilling Contractor's rig; drill and set rathole.

   (a) Notify Hawaii Board of Land and Natural Resources (BLNR) 24 hours prior to commencement of drilling.

   (b) Confirm compliance with all permit requirements.

   2.3 Spud hole with 17½ inch bit and mud drilling fluid; drill into top 20 feet of ground water zone. Stop and sample ground water.

   2.4 Drill ahead to 800 foot depth. Open hole to 26 inch. Control loss of circulation (LOC) with loss circulation material (LCM); cement severe lost circulation zones if required.

   2.5 Run 20 inch, 94 pound H-40 Buttress coupled casing to 800 feet. Single stage cement with 40 percent silica flour; use appropriate excess slurry. Be prepared to cement the 20-30 inch annulus with from the surface. Hold casing in tension during annular cement job. Wait on cement (WOC) 8 hours.

   2.6 Install 20 inch blow-out prevention equipment (BOPE) consisting of 20" casing head flange with 2 each 3" outlets for kill line and blow down line, 20" annular preventer and top mating flange and pitcher nipple assembly (see Figure B-2).

APPENDIX B
(continued)

Well Drilling and Completion Program

Notify the Chairman of the BLNR in advance of the BOP test so that a designated representative can witness the test.

Test BOP assembly to 500 psig. Enter test results on contractor and operator daily reports.

2.7 Install mud logging service before drilling out 20" casing. Record: continuous mud in and out temperatures, H_2S, CH_4, CO_2, lithology, and drilling rate. Have pit level indicator and intercom to driller stations. Catch four sets of 50 gram dry sample every 20 feet. Make daily copies of the mud log, keeping one copy up to date and available on site.

2.8 Drill 17½ inch hole to 2000 foot depth with mud drilling fluid. Survey wellbore every 200 feet, or on bit change. Use LCM or cement to control LOC as necessary.

2.9 Run 13 3/8 inch, 61 pound k-55 Buttress thread coupled casing to 2000 feet. Cement with 2200 cubic feet cement mixed 1:1 perlite, 40% silica flour, followed by 320 cubic feet cement mixed with 40% silica flour (note; provides for 100% excess). WOC 12 hours. If annular cement placement (top job) is needed hold casing in tension until final WOC is finished (i.e. do not release casing until cement is set at surface).

2.10 Install 13 5/8 inch BOPE consisting of the following items: 13 3/8" 900# casing head flange, 13 5/8" 3000 psi double gate BOP, 3000 psi double gate BOP, 3000 psi annular preventer, mating flange and riser with pitcher nipple (see Figure B-3). Hook up kill lines and blow down lines. Casing head welding to be performed with pre- and post-flange heating by a certified welder.

Notify the Chairman of the BLNR in advance of BOP test so that a designated representative can witness the test.

APPENDIX B
(continued)

Well Drilling and Completion Program

Pressure test BOP assembly to 1000 psig. Record results on contractor and operator's daily reports.

Confirm drill site location and operation of all H_2S safety equipment. Put all drill site personnel through H_2S safety review including equipment downing by each person.

2.11 Drill out cement with 12¼ inch mill tooth bit. Pull out of hole, pick up button bit and drill 12¼ inch hole to 2500 feet with mud. Run deviation survey every 200 feet.

2.12 Pull out of hole and pick up 12¼ inch directional type button bit, mud motor, 4° bent sub, monel drill collar and additional collars and drill pipe as needed. Build angle at 2-3° per 100 feet in desired direction for approximately 100 - 200 feet with mud motor. Pull out of hole and pick up bottom hole assembly with 12¼ inch button bit, near bit reamer, 2 each 9" drill collars, string stabilizer, shock sub, additional 9" and 8" drill collars, heavy weight drill pipe as needed. Build hole angle to 16° and hold to 4000 feet TVD. Run deviation and direction surveys as necessary (every 20 to 100 feet). Keep mud motor on location and use as necessary to maintain angle and hole direction. Maximum dog leg to be 2°/100 feet. Use soft banded drill pipe for drill pipe that is located inside the 13 3/8 inch casing. Ream hole as necessary as judged by several short trips and deviation data. Use LCM or cement to control LOC as necessary.

2.13 Run 9 5/8 inch, 47 pound, C-90, VAM-AF (or equivalent) casing to bottom of 12¼ inch hole (±4000ft). Use centralizers every 120 feet through deviated portion of hole. Cement with 1850 cubic feet cement mixed with 1:1 perlite, 40% silica flour followed by 100 cubic feet cement mixed with 40% silica flour (provides for 100% excess). Wait on cement 12 hours. If annular (top) job is needed, hold casing tension until cement is set to surface.

APPENDIX B
(continued)

Well Drilling and Completion Program

2.14 Install wellhead assembly and BOPE.

If aerated mud or aerated water drilling is planned, wellhead and BOP will consist of 13 3/8" x 9 5/8", 900# WKM type S expansion spool (or equivalent), 10" 900# gate valve, 10" 3000 psi single gate BOP with steel pipe ram, 10" 3000 psi banjo box with 10" 3000 psi hydraulically actuated throttle valve on banjo box side outlet, 10" 3000 psi x 13 3/8" 3000 psi spool, 13 3/8" 3000 psi double gate BOP with steel pipe ram and blind ram, 13 3/8" 3000 psi annular preventer, and rotating head on top (see Figure B-4).

If mud or water drilling is planned, assembly will consist of 13 5/8" x 9 5/8" expansion spool, 10" valve as above, 10" x 13 3/8" spool and 13 3/8" double gate BOP and 13 3/8" annular preventer, mating flange and rizer with pitcher nipple (see Figure B-5).

Notify the BLNR and test BOP.

2.15 Pick up 8½" mill tooth bit and drill out cement from casing. Pull out of hole, pick up bottom hole drilling assembly. Drill 8½" hole with aerated mud or aerated water (or mud/water) to ±7000 feet. Take directional surveys approximately every 100-150 feet. Condition hole and make several short trips to insure no fill on bottom of hole.

2.16 Pull out of hole and pick up ±3070 feet of 7" 29#/ft-L80 BT&C slotted casing with double slip liner hanger and 7" tieback set on top, and 7" guide shoe on bottom. Casing to be slotted from 4000'- 6950'. Set liner hanger at ±3880 feet (120' above bottom of 9 5/8" casing). Leave approximately 50' of open hole below bottom of casing for thermal expansion and debris.

2.17 Run in hole with 3 1/2" drill-pipe and circulate out mud with water.

2.18 Rig down BOP and nipple up wellhead consisting of [expansion spool and one 900# 10" gate valve were

APPENDIX B
(continued)

Well Drilling and Completion Program

attached in (2.14) above] 1 additional 900# 10" gate valve, 10" 900# flow tee with 900# 10" gate valve on side outlet and 3" 900# swab valve on top of tee (see Figure B-6).

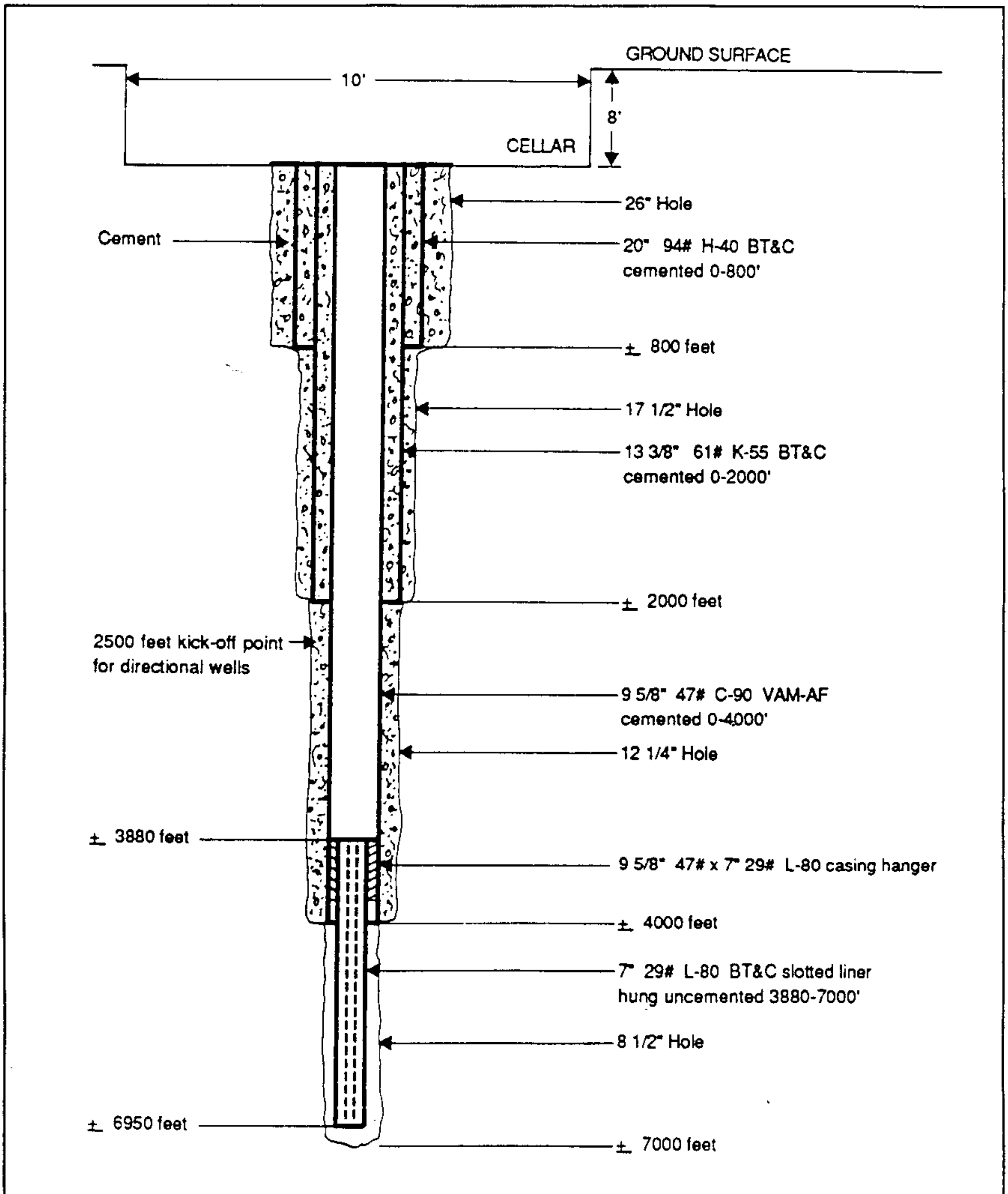


Figure B-1. Typical Puna Geothermal Venture Project Well Design

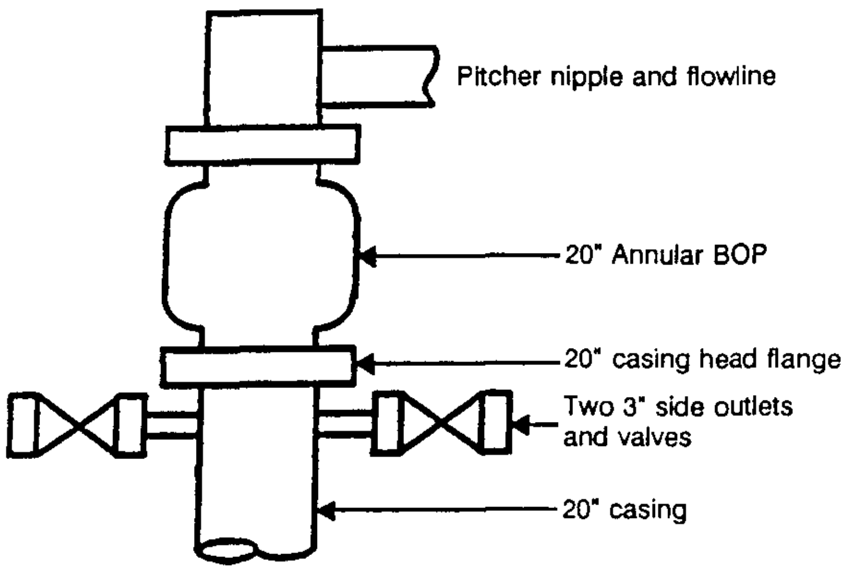


Figure B-2. 20" BOP Configuration

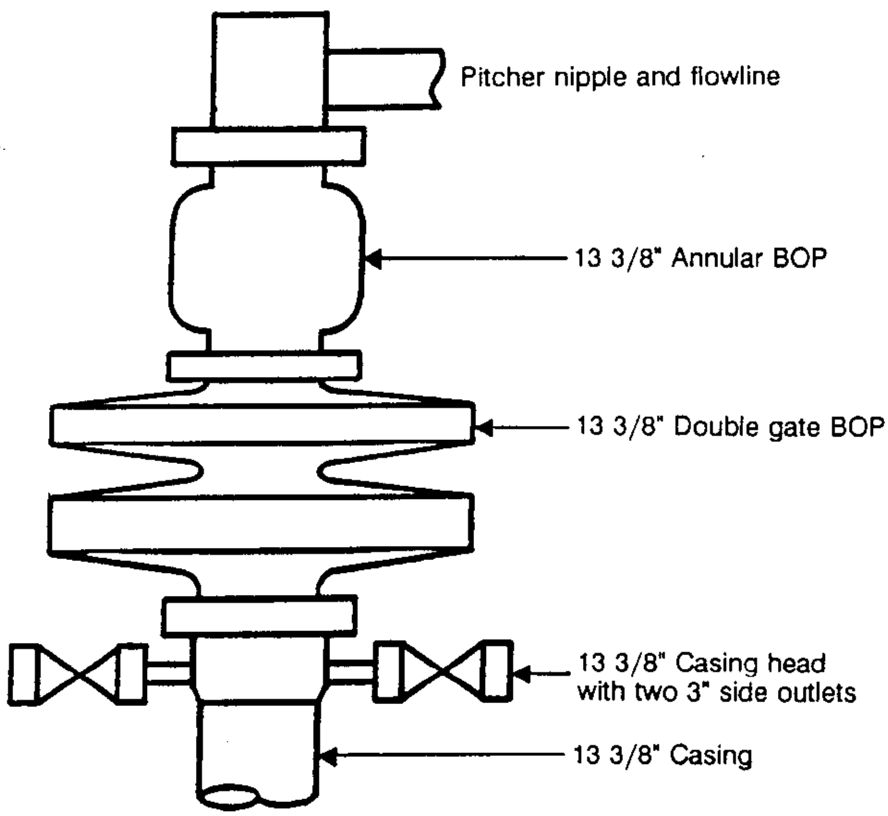


Figure B-3. 13 3/8" BOP Configuration

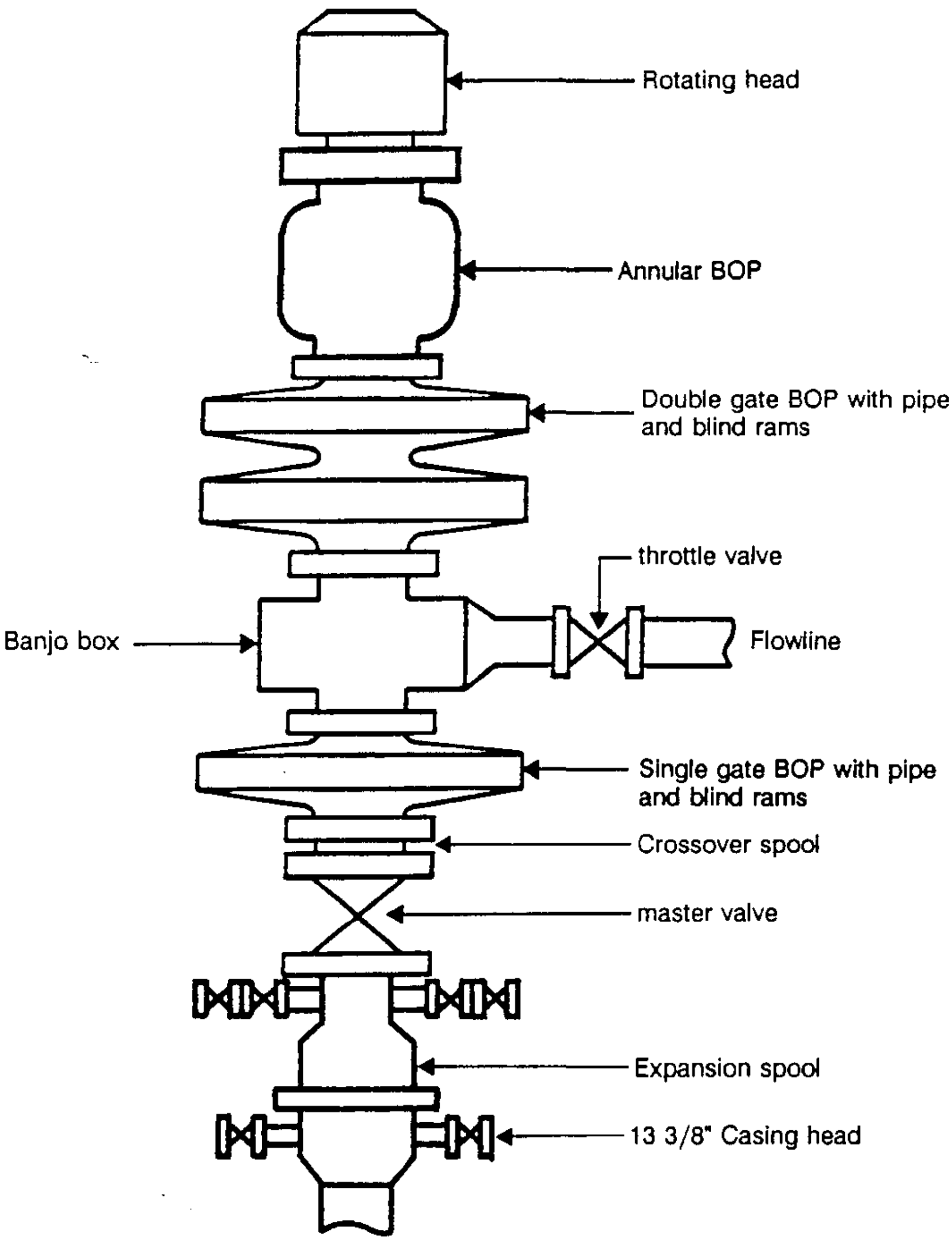


Figure B-4. 9 5/8" BOP Configuration, Aerated Mud Drilling

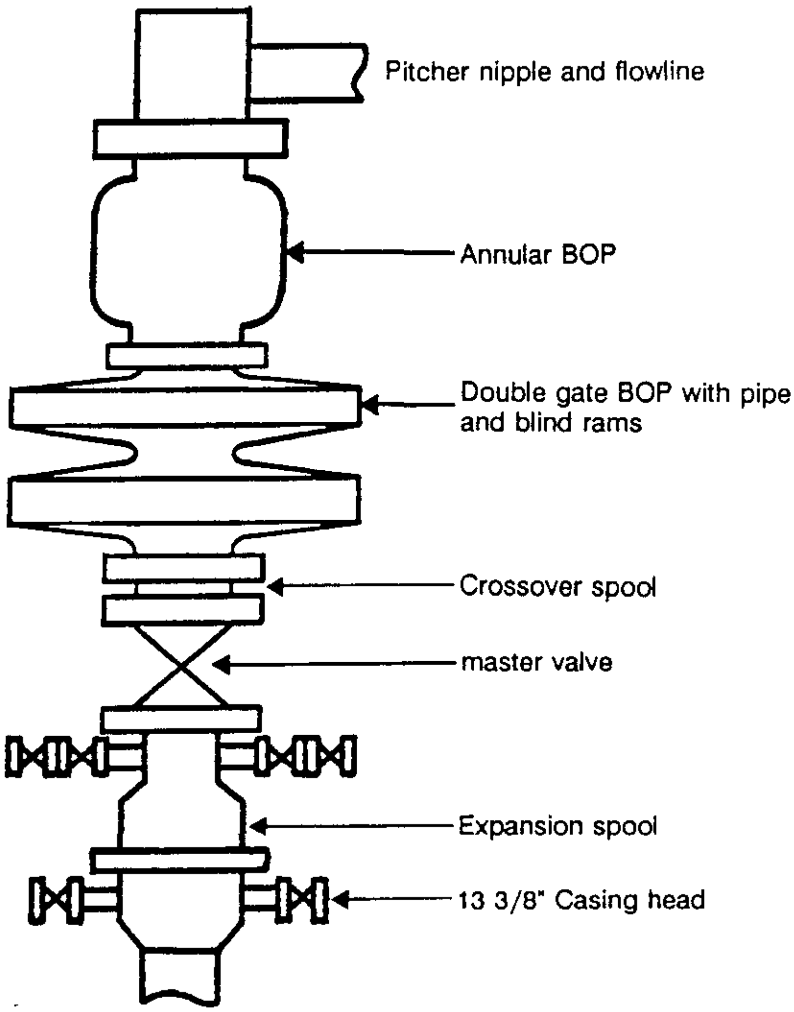


Figure B-5. 9 5/8" BOP Configuration, Mud Drilling

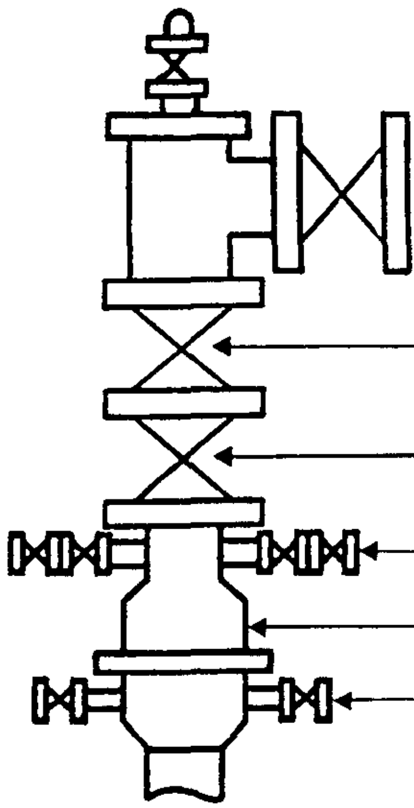
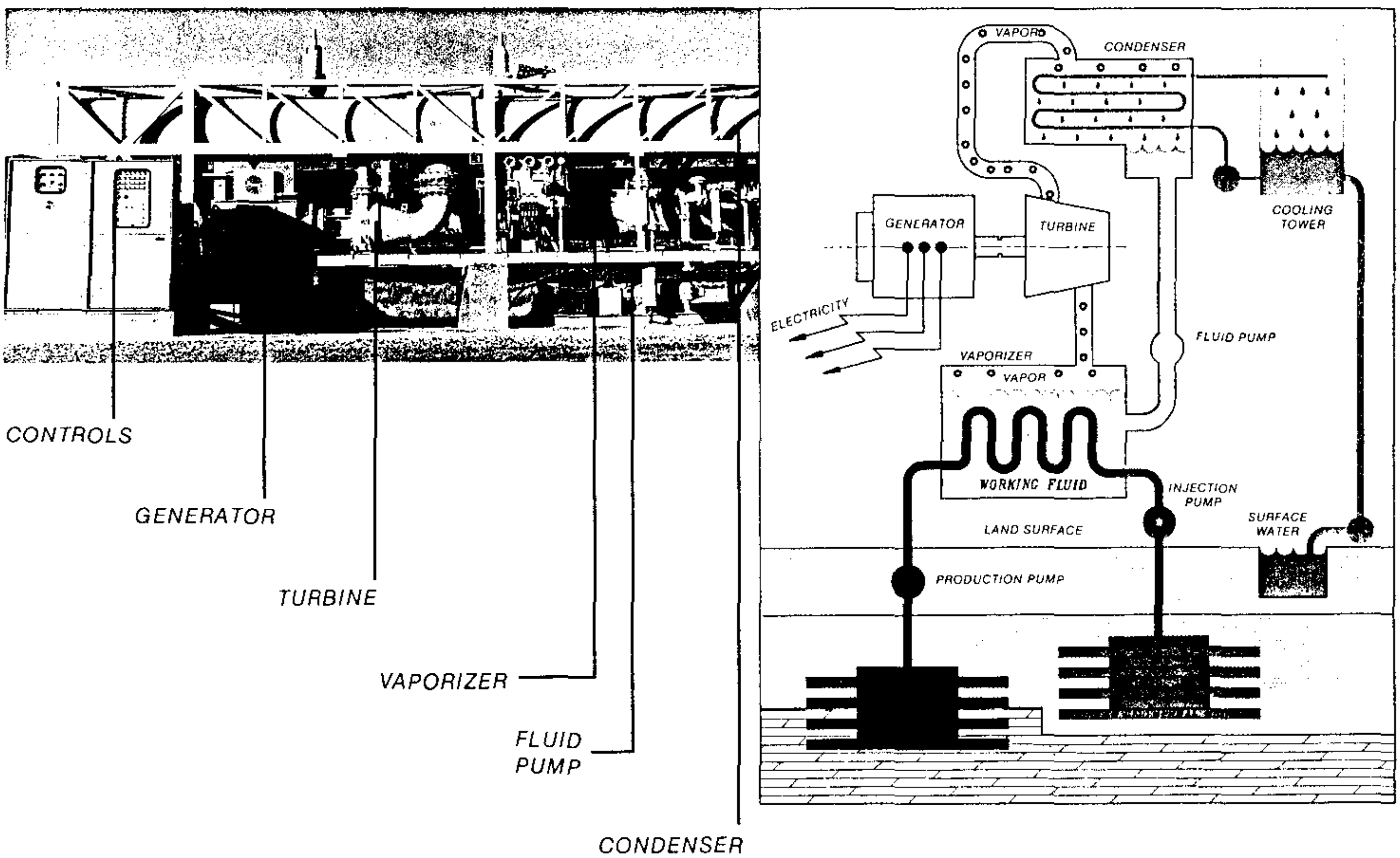


Figure B-6. Final Wellhead Configuration

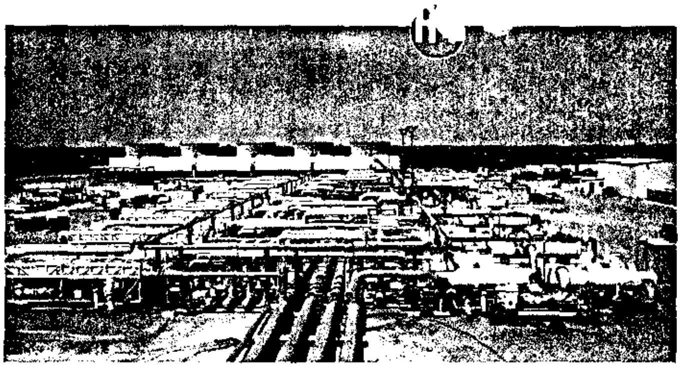
APPENDIX C - PHOTOGRAPHS OF GEOTHERMAL POWER PLANTS WHICH UTILIZE ORMAT ENERGY CONVERTER UNITS

How the ORMAT® Geothermal Power Plant Works

All **ORMAT®** *Geothermal Power Plant equipment packages are self-contained, fully automatic, producing grid compatible power. Like steam power plants, the* **ORMAT®** *system is based on the Rankine Power Cycle but uses an organic working fluid which has the advantage of being more efficient than steam when operating on low to moderate temperature geothermal fluids. The working fluid is selected to optimize the power output from given geothermal well water temperature and flow. Under production conditions, the working fluid is vaporized by the heat of the steam flowing through the vaporizer. The vapor expands as it passes through the organic vapor turbine which is coupled to the generator. The exhaust vapor is subsequently condensed in a water-cooled condenser or air cooler and is recycled to the vaporizer by the motive fluid cycle pump.*



ORMAT BINARY GEOTHERMAL POWER PLANT

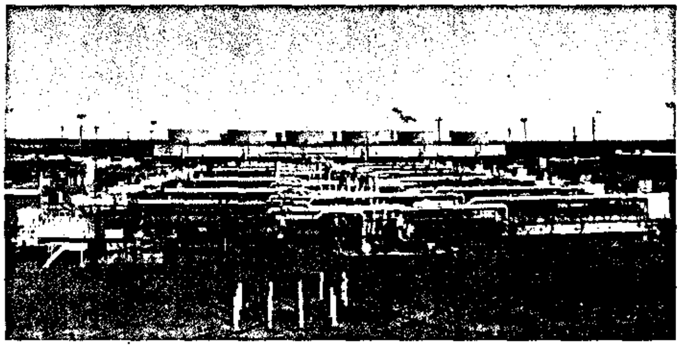


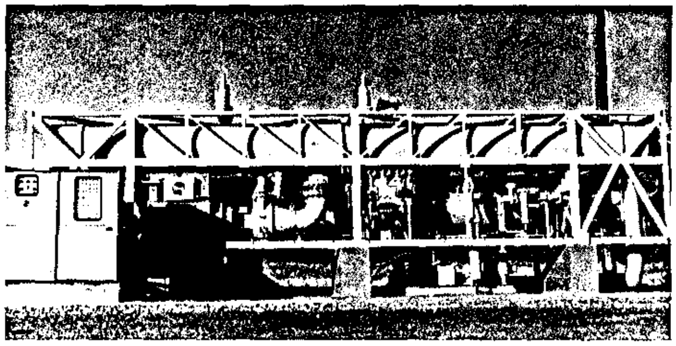
ORMESA GEOTHERMAL NO. 1

Located in Imperial County, California, this 30 MW (gross) modular power plant comprises 26 OECs arranged in three cascading levels. The power is wheeled by the Imperial Irrigation District (IID) for sale to Southern California Edison Company (SCE).

SODA LAKE GEOTHERMAL

Located near Fallon, Nevada, this 3.6 MW (gross) geothermal power plant includes three Ormat Energy Converters. The plant was completed and brought on-line in December 1987, and is presently selling electricity to Sierra Pacific Power Company.



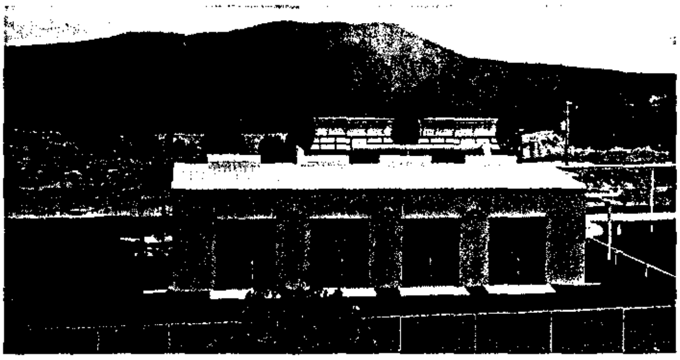


ORMESA GEOTHERMAL NO. 2

Also located in Imperial County, California, Ormesa Geothermal II is the sister project to Ormesa Geothermal I. This 20 MW plant consists of 20 OECs and was constructed and brought on-line within seven months. Power is sold to Southern California Edison Company.

TAD'S ENTERPRISES

Located near Wabuska, Nevada, this 1.76 MW (gross) plant is Ormat's first commercial geothermal application in the United States. The first unit, rated at 800 kW, was installed in 1984; the second unit, rated at 960 kW, was placed on-line in May 1987. The geothermal fluid inlet temperature is about 223°F. The plant is owned by Tad's Enterprises. Power is sold to Sierra Pacific Power Company.



COVE FORT GEOTHERMAL NO. 1

This 3.2 MW power plant is located in Sulphurdale, Utah, and consists of four OECs utilizing moderate pressure steam. The plant was built on a turnkey basis by Ormat for the City of Provo and Mother Earth Industries, and was commissioned in 1985.

STEAMBOAT GEOTHERMAL *(Cover):* Located in Steamboat Springs, Nevada, this 7.4 MW (gross) air-cooled, modular power plant comprises seven OECs in two cascading levels. Full commercial power operation was achieved in 1986.

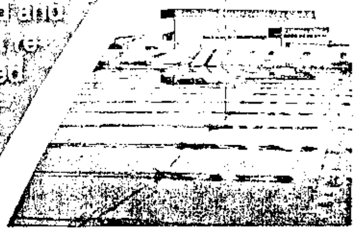
...RMAT ENERGY CONVER...

MODULAR POWER PLANTS

ORMAT'S modular factory integrated and tested concept results in shortened delivery and installation time and provides the most cost-effective system

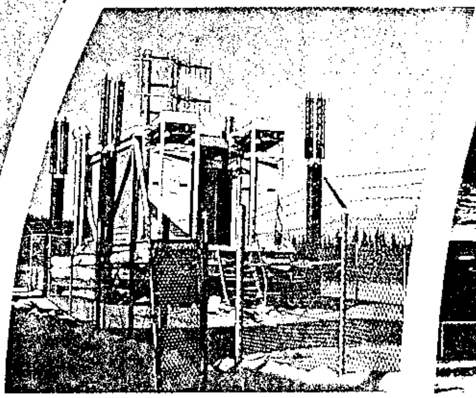
[illegible] Years Experience With Organic Rankine Cycle Systems

Full System Capability

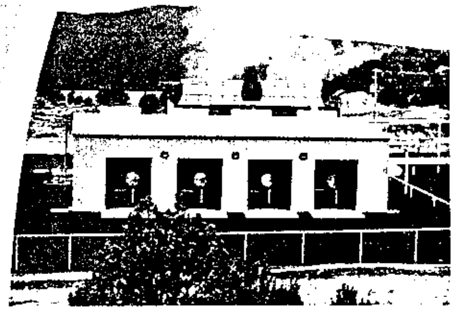


5 Megawatt Solar Pond Power Plant

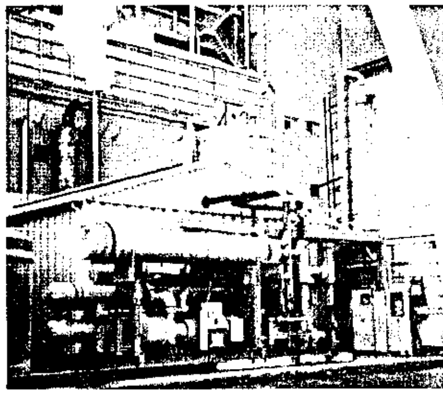
Soda Lake Geothermal - Nevada



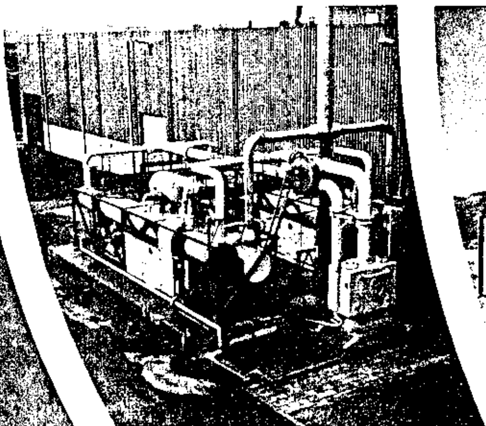
Ormat Energy Converters — Trans Alaska Pipeline



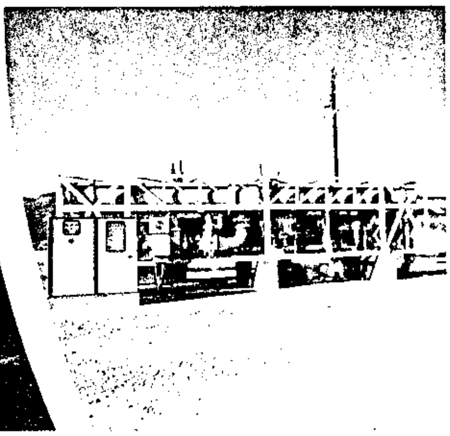
3.2 Megawatt Geothermal Power Plant — Utah



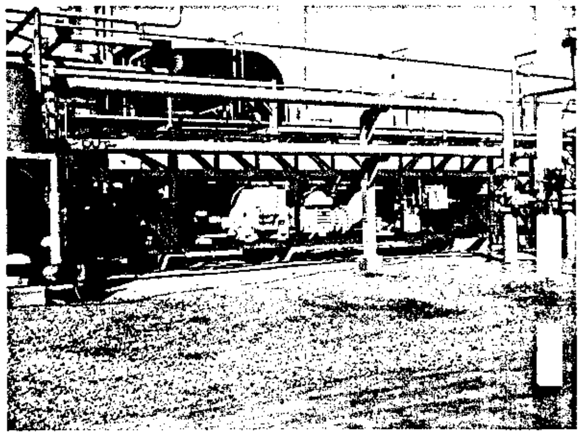
Waste Heat Recovery - Refuse Incineration



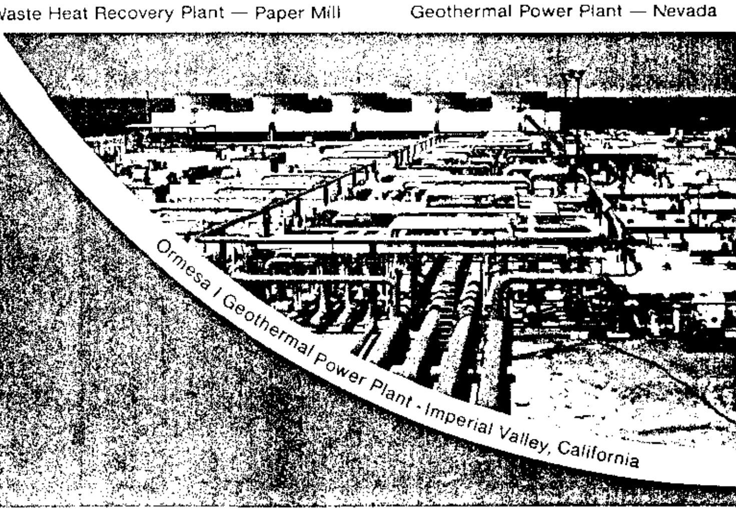
Waste Heat Recovery Plant — Paper Mill



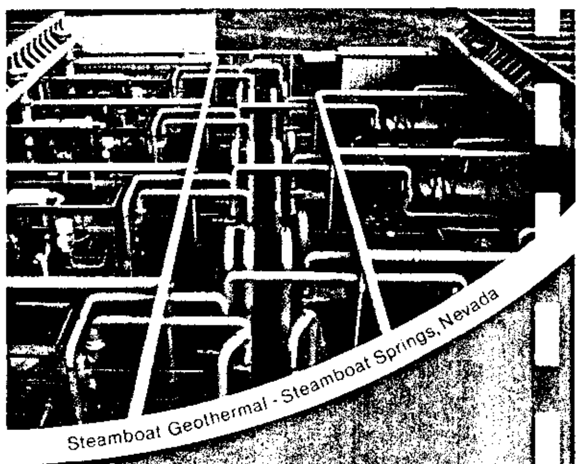
Geothermal Power Plant — Nevada



Waste Heat Recovery Hydrogen Plant — California



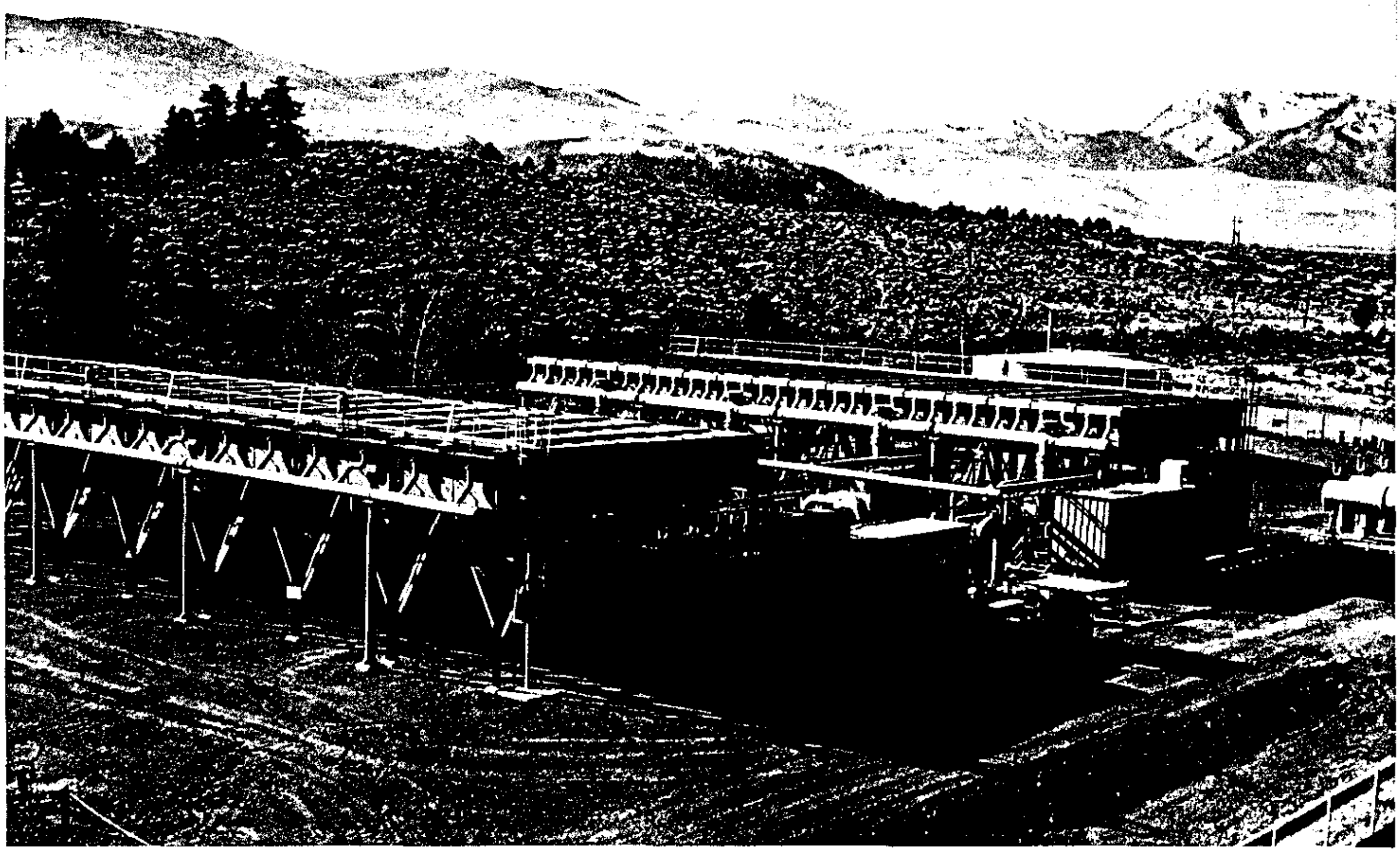
Ormesa I Geothermal Power Plant - Imperial Valley, California

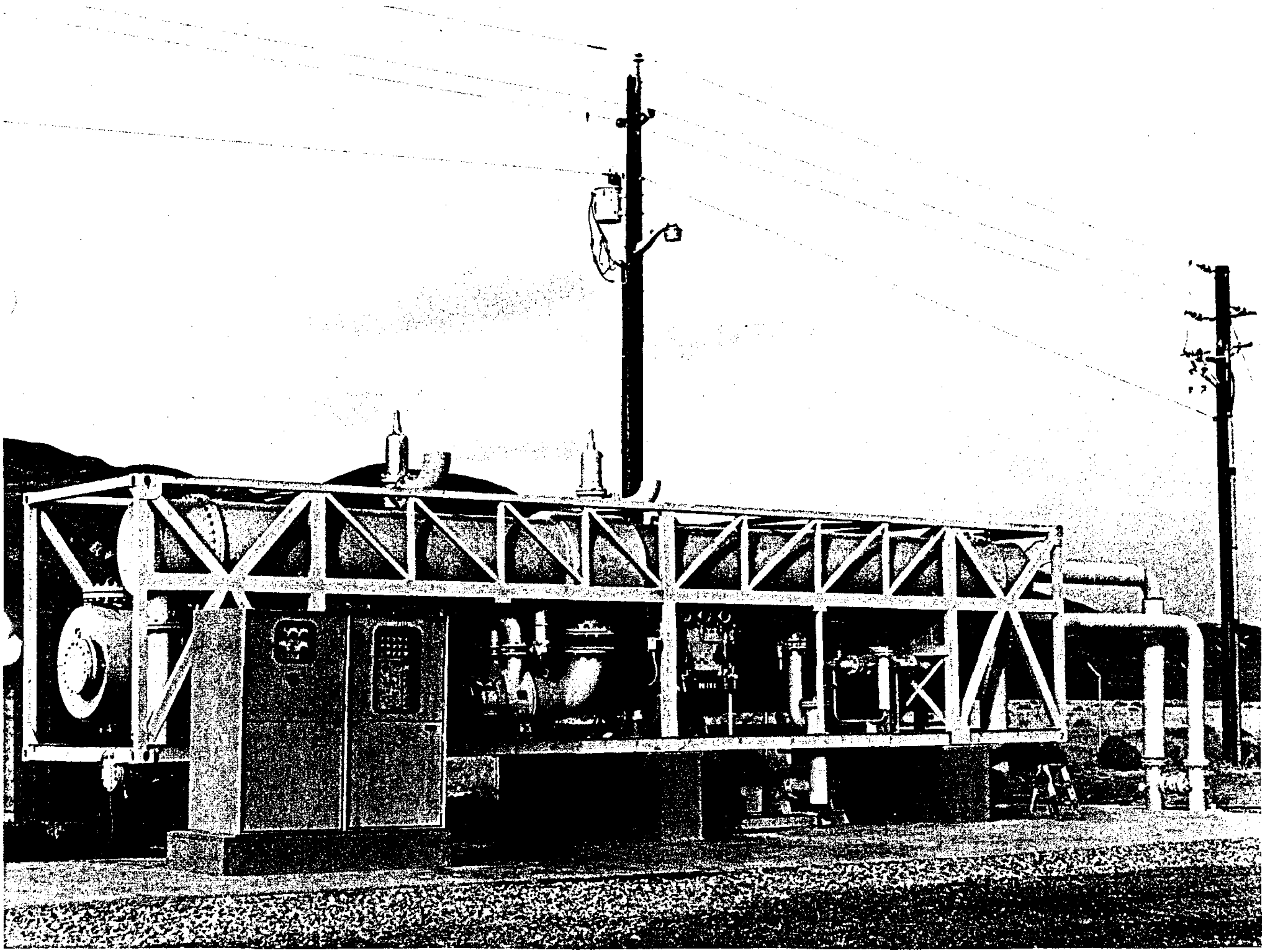


Steamboat Geothermal - Steamboat Springs, Nevada

ORMAT®

Geothermal Power Plants





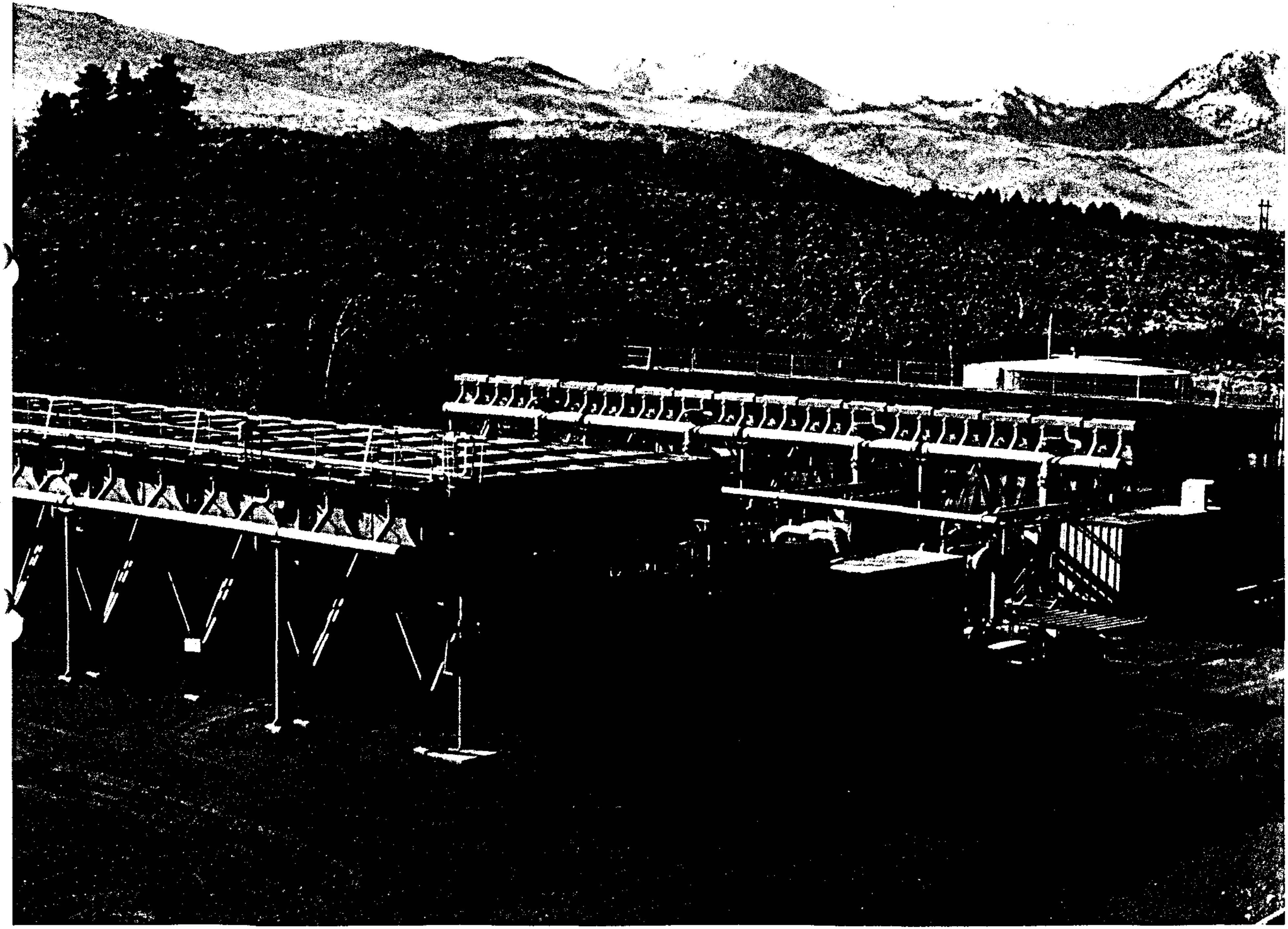
TAD'S ENTERPRISES, INC.

WABUSKA, NEVADA

FACT SHEET

- *This power plant is comprised of two Ormat Energy Converter (OEC) Modules.*
- *The first unit, shown here, rated at 800 kW, was installed and placed in service in 1984.*
- *The maintenance-free unit has been running unattended at 96% availability.*
- *This Ormat Energy Converter is a containerized, self-contained, factory integrated unit based on the Organic Rankine Cycle. The unit contains heat exchangers, turbine, generator, control system, valves, safety circuits and piping between components, all housed in an ISO 40-foot container frame.*
- *The plant operates on geothermal water at a temperature of 223°F only. The hot water is pumped from a depth of 300 feet.*
- *Cooling water for condensers is supplied from a cooling pond. Some of the geothermal water is used as make-up water for the pond.*
- *Power plant flow rates, pressures and temperatures are monitored and controlled for optimum system operation.*
- *The 480 volt, three-phase 60 Hz electrical power is fed to the grid through a step-up transformer.*
- *Power from the plant is sold to Sierra Pacific Power Company (SPPC).*
- *Following the successful operation of the first unit, a second 960 kW unit was placed in service in 1987.*
- *Ormat has been designing and manufacturing innovative power plants based on the Organic Rankine Cycle Technology since 1965. Over 3,500 Ormat Energy Converters are currently in use worldwide.*

ORMAT®



STEAMBOAT GEOTHERMAL

STEAMBOAT SPRINGS, NEVADA

FACT SHEET

- *5.2 MW (net) modular power plant comprised of seven Ormat Energy Converter (OEC) Modules. The power plant was designed and built on a turnkey basis by Ormat.*

- *The modular power plant operates on liquid dominated source at 338°F to 345°F. It utilizes dry air condensers to condense the organic fluid, as no makeup water is available.*

- *Construction was initiated in October 1985. Full power production commenced in late 1986.*

- *The project is owned by Far West Hydroelectric Fund and operated by Ormat Inc. The power is sold to Sierra Pacific Power Company (SPPC).*

- *The current availability factor is 90%.*

- *Power plant flow rates, pressures and temperatures are computer monitored and controlled for optimum system operation.*

- *The power is generated by the 1200 kW OEC's at 600 volts, three-phase 60 Hz and is fed to the grid through step-up transformers.*

- *The anticipated useful life of the plant is 30 years.*

- *The plant was designed for failsafe, automatic operation.*

- *The Ormat Energy Converter Modules are containerized, self-contained, factory integrated units based on the Organic Rankine Cycle. They include heat exchangers, turbine, generator, control system, valves, safety circuits and piping between components all in an ISO 40-foot container frame.*

- *Ormat has been designing and manufacturing innovative power plants based on the Organic Rankine Cycle Technology since 1965. Over 3,500 Ormat Energy Converters are currently in use worldwide.*

ORMAT

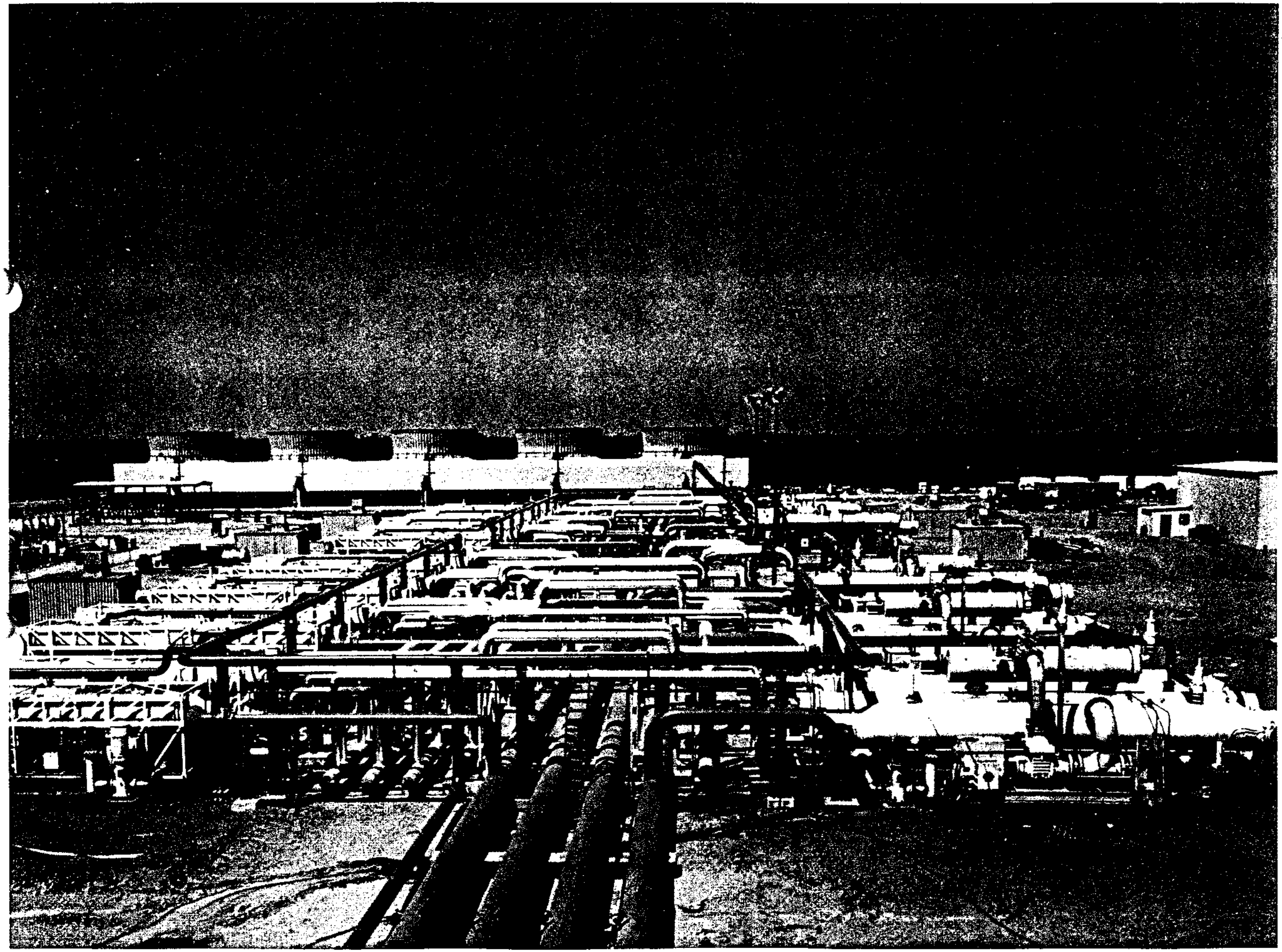
COVE FORT GEOTHERMAL NO. 1

SULPHURDALE, UTAH

FACT SHEET

- *The Cove Fort power plant was designed and built on a turnkey basis by Ormat Inc., for the City of Provo Municipal Utility and Mother Earth Industries.*
- *The plant was commissioned in September 1985.*
- *Phase I of the power plant consists of four Ormat Energy Converter (OEC) Modules. The net generated power varies from 2.5 to 2.7 MW.*
- *The OEC units operate on condensing steam with a significant non-condensible gas content.*
- *The current availability factor exceeds 90%.*
- *Power plant flow rates, pressures and temperatures are computer monitored and controlled for optimum system operation.*
- *The computer control system incorporates remote diagnostic and monitoring capabilities. Real-time system and operating data received by the City of Provo's main control center.*
- *Cooling water system incorporates a mechanical draft cooling tower.*
- *Phases II and III will incorporate additional Ormat Energy Converters in series with back pressure steam turbines.*
- *Ormat has been designing and manufacturing innovative power plants based on the Organic Rankine Cycle Technology since 1965. Over 3,500 Ormat Energy Converters are currently in use worldwide.*

ORMAT



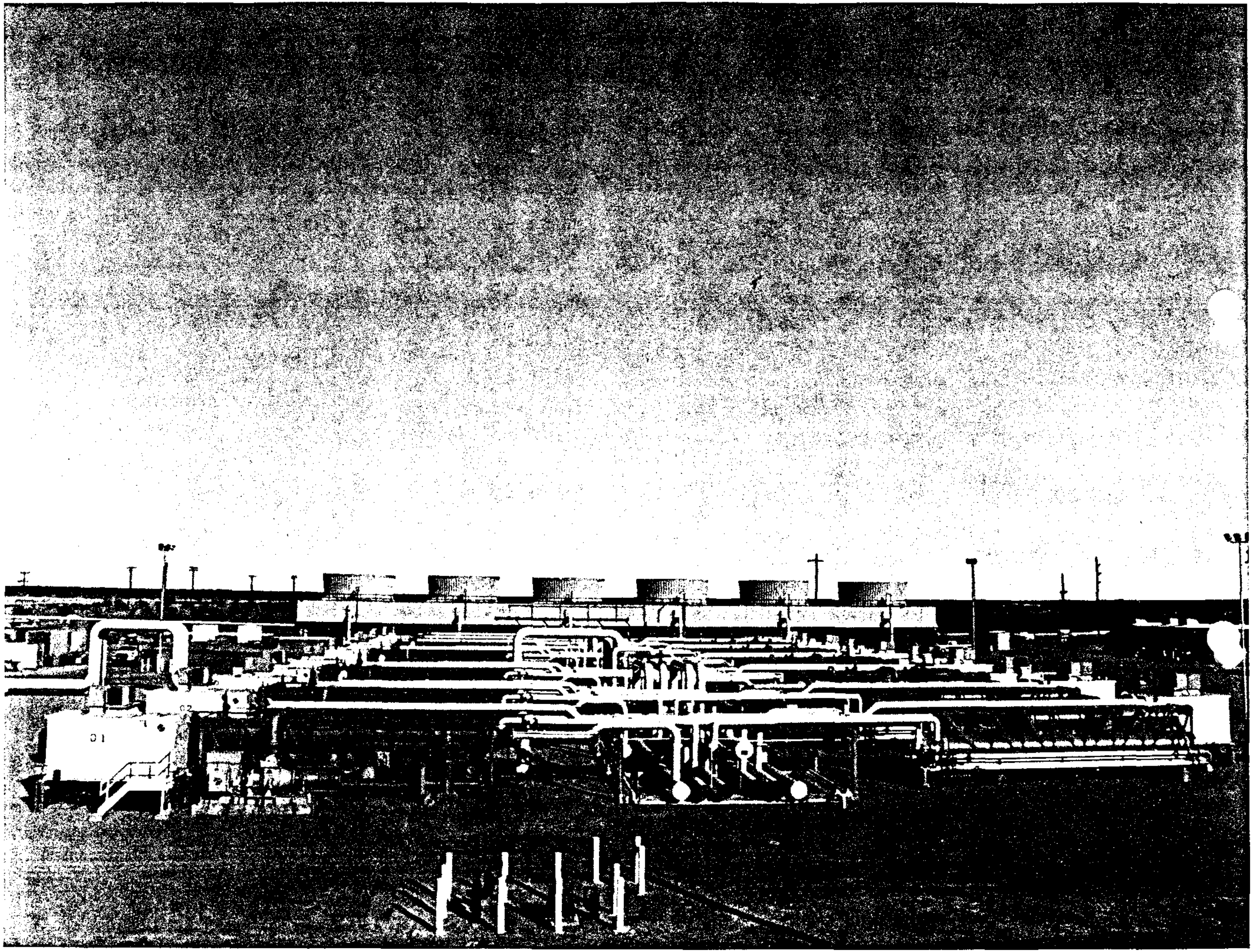
ORMESA I GEOTHERMAL POWER PLANT

EAST MESA, CALIFORNIA

FACT SHEET

- *24 MW (net) modular power plant comprised of 26 Ormat Energy Converters (OECs) in three cascaded levels.*
- *Power plant flow rates, pressures and temperatures are computer monitored and controlled for optimum system operation.*
- *The Ormat Energy Converter Modules are containerized, self-contained, factory integrated units based on the Organic Rankine Cycle. They include heat exchangers, turbine, generator, control system, low voltage switchgear, valves, safety circuits and piping between skid-mounted components.*
- *Power is wheeled by the Imperial Irrigation District (IID) for sale to Southern California Edison (SCE).*
- *Construction commenced July 1986.*
- *Synchronized to the grid in December 1986.*
- *Ormat has been designing and manufacturing innovative power plants based on the Organic Rankine Cycle Technology since 1965. Over 3,500 Ormat Energy Converters have been supplied worldwide.*
- *Ormesa II, 16.5 MW (net), under construction as of August 1987.*

ORMAT



ORMESA II
GEOTHERMAL POWER PLANT

EAST MESA, CALIFORNIA

FACT SHEET

- *20 MW (gross) modular power plant comprising 20 Ormat Energy Converters (OECs) arranged in two cascaded levels.*
- *Geothermal field consisting of seven production and four injection wells.*
- *Power plant and geothermal well flow rates, pressures and temperatures are computer monitored for optimum system operation.*
- *The Ormat Energy Converter Modules are containerized, self-contained, factory integrated units based on the Organic Rankine Cycle. They include heat exchangers, turbine, generator, control system, low voltage switchgear, valves, safety circuits and piping between skid-mounted components.*
- *Power is wheeled by the Imperial Irrigation District (IID) for sale to Southern California Edison.*
- *Power plant construction and geothermal field development commenced in June 1987 and were completed within seven months.*
- *Synchronized to the grid in December 1987.*
- *Ormat has been designing and manufacturing innovative power plants based on the Organic Rankine Cycle Technology since 1965. Over 3,500 Ormat Energy Converters have been supplied worldwide.*

ORMAT

APPENDIX D - PRELIMINARY EMERGENCY PLAN OUTLINE FOR CONSTRUCTION AND OPERATIONS

Section	Comments
1. Introduction	Define purpose and scope of plans.
2. Facility Description and Operation	Identify potential emergency situations.
3. Outside Emergency Services	Describe coordination agreements with outside organizations and services available.
4. Onsite Emergency Responsibilities	Define chain of command and specific responsibilities of security, maintenance, and management personnel.
5. Potential Project Hazards	
5.1 Well Blowouts	
5.1.1 Onsite Prevention Equipment	Describe emergency equipment/systems, location, use. Identify personnel trained in equipment/system usage.
5.1.2 Warning Systems	Identify onsite warning systems and proper responses.
5.1.3 Control Measures	Identify steps to be followed to control emergency.

APPENDIX D
(continued)

Preliminary Emergency Plan Outline
for Construction and Operations

Section		Comments
5.2	H_2S Hazards	
5.2.1	Onsite Prevention Equipment	Describe emergency equipment/systems, location, use. Identify personnel trained in equipment/systems usage.
5.2.2	Warning Systems	Identify onsite warning systems and proper responses.
5.2.3	Control Measures	Identify steps to be followed to control emergency.
5.3	Isopentane Hazards	
5.3.1	Onsite Prevention Equipment	Describe emergency equipment/systems, location, use. Identify personnel trained in equipment/system usage.
5.3.2	Warning Systems	Identify onsite warning systems and proper responses.
5.3.3	Control Measures	Identify steps to be followed to control emergency.
5.4	Fires	
5.4.1	Onsite Equipment	Describe emergency equipment/systems, location, use. Identify personnel trained in equipment/system usage.
5.4.2	Warning Systems	Identify onsite warning systems and proper responses.

APPENDIX D
(continued)

Preliminary Emergency Plan Outline
for Construction and Operations

Section	Comments
5.4.3 Control Measures	Identify steps to be followed to control emergency.
5.5 Pipeline Ruptures	
5.5.1 Warning Systems	Identify onsite warning systems and proper responses.
5.5.2 Control Measures	Identify steps to be followed to control emergency.
5.6 Chemical Spills	
5.6.1 Onsite Prevention Measures	Describe emergency equipment/systems, location, use. Identify personnel trained in equipment/system usage.
5.4.2 Warning Systems	Identify onsite warning systems and proper responses.
5.4.3 Control Measures	Identify steps to be followed to control emergency.
6. Natural Hazards	
6.1 Lava Flows	
6.1.1 Design Measures	Discuss design and response measures.
6.1.2 Warning Systems	Identify onsite warning systems and proper responses.
6.1.3 Control Measures	Identify steps to be followed to control emergency.

APPENDIX D
(continued)

Preliminary Emergency Plan Outline
for Construction and Operations

Section	Comments
6.2 Earthquakes	
6.2.1 Design Measures	Discuss design and response measures.
6.2.2 Warning Systems	Identify onsite warning systems and proper responses.
6.2.3 Control Measures	Identify steps to be followed to control emergency.
6.3 Hurricanes	
6.3.1 Design Measures	Discuss design and response measures.
6.3.2 Warning Systems	Identify onsite warning systems and proper responses.
6.3.3 Control Measures	Identify steps to be followed to control emergency.
7. Medical Emergencies	Identify medical facilities and transportation plans.
8. Evacuation Plan	Define procedures for emergency evacuation for lava flow, hurricane, etc. Includes meeting points and personnel roster.
9. Authority Notification	Define proper authorities to contact and notification requirements associated with various emergencies.

APPENDIX D
(continued)

Preliminary Emergency Plan Outline
for Construction and Operations

	Section	Comments
10.	Media Notification	Identify personnel who can make statement of what happened and what is the threat to the public. Identify personnel who are responsible for notifying the media.
11.	Emergency Reporting and Recordkeeping.	Specify compliance measures with regulatory requirements. Describe reporting and recordkeeping procedures.
12.	Hazard Check List	Provide a check list to help define the emergency, the selection of control measures, when to evacuate, and when to notify outside services and agencies.

ORMAT®

January 18, 1989
Reference No. 89011

Mr. William W. Paty, Chairperson
Board of Land and Natural Resources
Kalanimoku Building
1151 Punchbowl Street
Honolulu, Hawaii 96813

Re: Geothermal Mining Lease R-2 - Amendment to Plan of Operation for the 25 MW Puna Geothermal Venture Project

Dear Chairman Paty:

AMOR VIII Corporation (AMOR VIII), as designated operator for Geothermal Mining Lease R-2, hereby requests that the Board of Land and Natural Resources (BLNR), pursuant to Department of Land and Natural Resources (DLNR) Administrative Rules, Title 13, Chapter 183, Sections 55 and 56, accept this letter and its attachment as an amendment to the previously submitted Plan of Operation (Plan) for the 25 MW Puna Geothermal Venture Project (PGV Project) power plant and associated geothermal wellfield. The PGV project is proposed for Geothermal Mining Lease R-2, which is located in the Kapoho section of the Kilauea Lower East Rift Geothermal Resources Subzone in the Puna District of the Island of Hawaii. The project will sell the generated electricity to the Hawaii Electric Light Company (HELCO) for use on the Island of Hawaii.

On December 8, 1986, Thermal Power Company (TPC), then the designated operator of the Puna Geothermal Venture partnership, submitted a Plan of Operation to the BLNR for the PGV Project. The BLNR deferred processing of the PGV Project Plan while TPC, at TPC's request, proceeded with the preparation of an Environmental Impact Statement (EIS) for the PGV Project. Subsequent to acceptance of the Final EIS for the PGV Project by the Hawaii County Planning Department, no further processing of the submitted Plan has taken place because the entire interest in the PGV partnership was purchased during the first half of 1988 by AMOR VI Corporation and AMOR VIII Corporation (AMOR Corporations), two wholly-owned subsidiaries of Ormat Energy Systems, Inc. of Sparks, Nevada (please refer to letters dated August 2, 1988, October 6, 1988 and October 24, 1988 to your office for additional information regarding Puna Geothermal Venture).

Since their purchase of all the interests to PGV and the PGV Project, the AMOR Corporations have reviewed the TPC design of the PGV Project to determine if it remains entirely appropriate. As a result of this design review, the AMOR Corporations have decided to alter several aspects of the PGV Project proposed by TPC to optimize projection operations and further reduce the potential for environmental impacts. Principal among these proposed changes is the use of back-pressure steam turbines, in combination with air-cooled binary cycle turbines, in place of the steam turbines and cooling towers proposed by TPC. This proposed power plant configuration applies a closed cycle for the geothermal fluid, thus eliminating the need for cooling water. Besides essentially eliminating hydrogen sulfide emissions, most other environmental impacts from this project will be the same as those described in the PGV Project Final EIS because the AMOR corporations' proposed PGV Project will be located on the same site as the PGV Project proposed by TPC, and will use the same well pad locations and the same geothermal resource.

This amendment to the PGV Project Plan has been prepared to replace, in its entirety, the Plan of Operation for the PGV Project submitted to the BLNR in December, 1986. The amended Plan consists of this letter and a copy of the Geothermal Resource Permit (GRP) application amendment for this revised PGV Project, which was submitted to the Hawaii County Planning Department on December 30, 1988, as the GRP application amendment contains all the information required in Title 13, Chapter 183, "Rules on Leasing and Drilling of Geothermal Resources," Section 55, "Plan of Operation Required." The following concordance compares the information requirements of Section 13-183-55 with the sections of the Puna Geothermal Venture GRP application amendment:

> "(1) The proposed location and elevation above sea level of derrick, proposed depth, bottom hole location, casing program, proposed well completion program and the size and shape of drilling site, excavation and grading planned, and location of existing and proposed access roads;"

The locations and elevations of the six proposed wellpads on which the 150-foot derrick will be placed are discussed in Section 3.2.1.1. Wellpads and Access Roads. This section also describes the size and shape of the drilling sites and the location of the existing and proposed access roads. Project elevations are discussed in Section 3.4. Elevation of Structures.

The proposed depth, bottom hole locations, casing program, and the proposed well completion program are discussed in Section 3.2.1.2. Well Drilling. Appendix B contains additional information on the well casing and well completion program. Information on injection casing is contained in Section 3.2.1.6. Geothermal Fluids Injection System.

Excavation and grading plans are presented in Section 3.6. Surface Disturbance.

> "(2) Existing and planned access, access controls and lateral roads;"

The existing and planned access roads are presented in Section 3.2.1.1. Well Pads and Access Roads and Section 3.10.8.1. Traffic. Access control is discussed in Section 3.2.3.6. Fencing and in Section 3.10.6. Protection of Public Health and Safety.

January 18, 1989
Reference No. 89011
Page 3

"(3) Location and source of water supply and road building material;"

No water will be needed for power plant cooling. The location and source of water supply for service water is discussed in Section 3.3. Plot and Site Plans. No significant amount of road building materials will be needed for the project. Most access roads will be improved from existing agricultural roads, and only Wellpad F will require a new road.

"(4) Location of camp sites, air-strips, and other supporting facilities;"

The location of the temporary construction yard is shown on Figure 2-1. No air strip or other supporting facilities are proposed for the project.

"(5) Other areas of potential surface disturbance;"

Surface disturbance is discussed in Section 3.6. Surface Disturbance.

"(6) The topographical features of the land and the drainage patterns;"

Figure 3-2 is a topographical map of the project area. Drainage is described in Section 3.2.3.4. Site Drainage Facilities and Section 3.8. Geologic Report.

"(7) Methods of disposing of well effluent and other waste;"

Section 3.7. Disposal of Well Effluent and Other Waste discusses disposal of geothermal brines, condensate and noncondensable gases as well as other wastes. Further detail is provided in Section 3.2.1.6. Geothermal Fluids Injection System. Well testing effluents are discussed in Section 3.2.1.3. Well Testing.

"(8) A narrative statement describing the proposed measures to be taken for protection of the environment, including, but not limited to the prevention or control of:

(A) Fires,
(B) Soil erosion,
(C) Pollution of the surface and ground water,
(D) Damage to fish and wildlife or other natural resources,
(E) Air and noise pollution, and
(F) Hazards to public health and safety during lease activities.

Section 3.10. Environmental Protection is a written description of the measures to be taken to protect the environment. It includes the following subsections: 3.10.1. Fire Protection; 3.10.2. Erosion Control; 3.10.3. Protection of Sruface Waters and Groundwater; 3.10.4. Protection

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Page 4

"(9) A geologist's preliminiary survey report on the surface and sub-surface geology, nature and occurrence of the known or potential geothermal resources, surface water resources, and ground water resources;"

Section 3.8. Geologic Report describes the surface and subsurface geology, the nature and occurrence of the known or potential geothermal resources, surface water resources and groundwater resources.

"(10) All pertinent information or data which the chairperson may require to support the plan of operations for the utilization of geothermal resources and the protection of the environment;"

The PGV project GRP contains additional details on the project, particularly in Section 3.2. Project Scope and Description. If the chairperson requires further information, it will be provided upon request.

"(11) Provision for monitoring deemed necessary by the chairperson to insure compliance with these rules for the operations under the plan."

Section 3.12. Monitoring Plans lists the monitoring activities proposed by PGV to show compliance with regulations. This discussion includes the following subsections: 3.12.1. Meteorological and Air Quality Monitoring; 3.12.2 Noise Monitoring; 3.12.3. Biological Monitoring; and 3.12.4. Compliance with Regulations, including the DLNR regulations in Chapter 183.

The plot plan and other drawings have been reduced for ease of copying. Larger size drawings are available if the DLNR staff requires them for their review. In addition, fourteen additional copies of the attachment to this letter, the PGV Geothermal Resource Permit application amendment, have been delivered under separate cover to the staff of the DLNR to facilitate the BLNR's review of the Plan.

Please do not hesitate to contact me if you have questions concerning the PGV Project or if we can be of any assistance in your timely review and approval of the Plan of Operation.

Sincerely yours,

AMOR VIII Corporation

Maurice A. Richard

by Maurice A. Richard
its Designated Agent

cc:

Geothermal Subzone
Kilauea Middle East Rift Zone

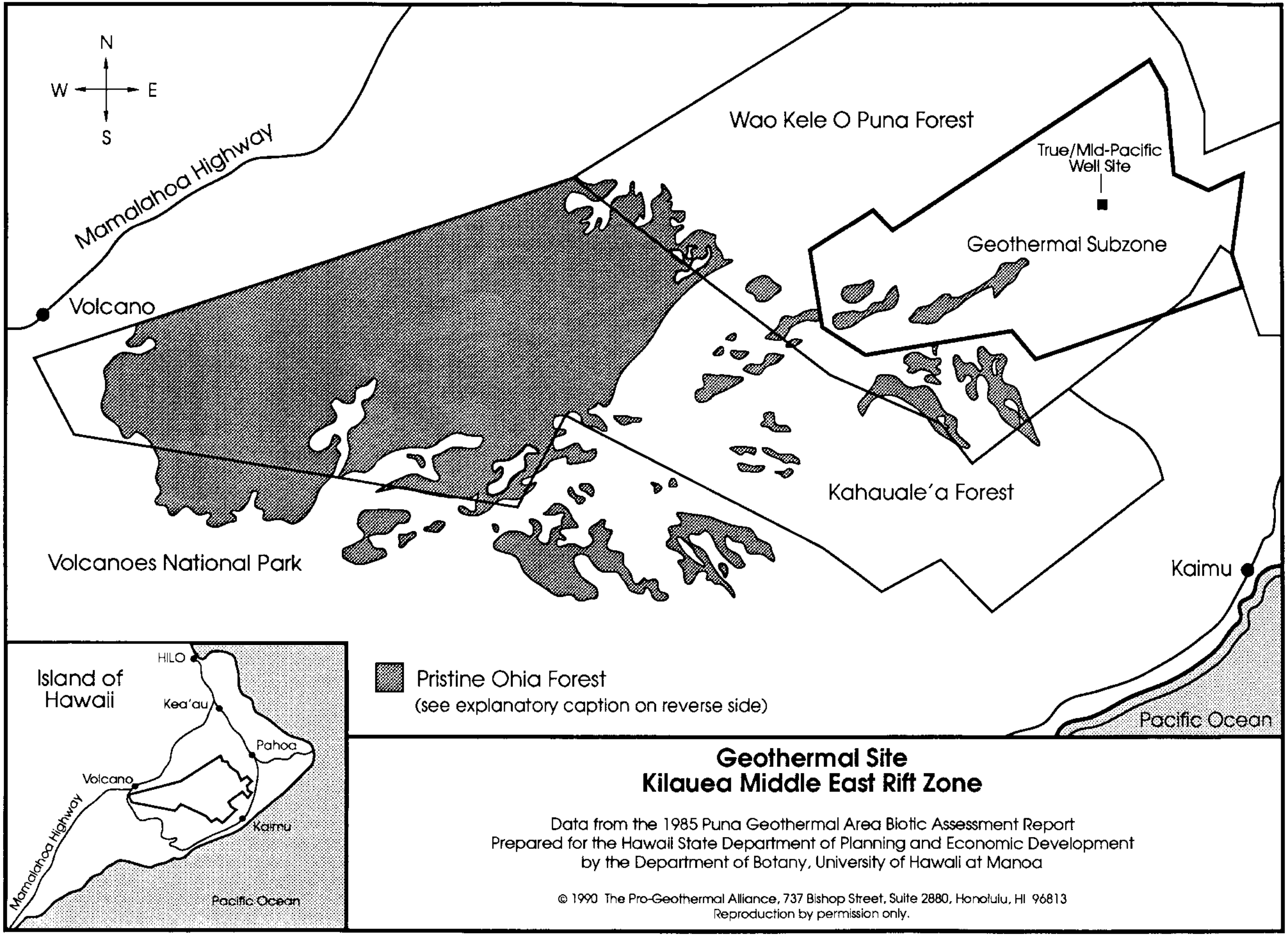
The Puna forest in the Kilauea East Rift Zone of the Big Island consists of 60,000 contiguous acres and is one of several rain forests in the state of Hawaii. In 1985 the State requested a biotic assessment of the Puna forest that enabled biologists to map the area's vegetation.

Results of the assessment showed a large expanse of pristine forest in Kahauale'a with ohia and other native flora. Several small areas of pristine forest were also located in Wao Kele O Puna. Outside these areas, the Puna forest hosts native flora that has been invaded, to varying degrees, by alien species such as the strawberry guava, which inhibit the growth of native species.

Community residents, environmentalists, the National Park Service and the State Land Board encouraged preservation of Kahauale'a and the relocation of a Geothermal Resource Subzone that was designated within its boundaries. They proposed a land exchange that moved geothermal development to a site within 27,000 acres of less pristine land in Wao Kele O Puna and placed the 25,000 acres of Campbell Estate land in Kahauale'a under State control. An agreement was reached at the end of 1985, and the exchange was completed in early 1986.

Besides the geothermal subzone shown on this map, the Big Island also has a sub-zone in Pohoiki, just outside the rain forest. Geothermal development in Wao Kele O Puna is being kept away from pristine ohia areas and is expected to utilize less than 1 percent of the land area in the Puna forest.

ProGEO
The Pro-Geothermal Alliance
737 Bishop Street, Suite 2880 • Honolulu, Hawaii 96813



Geothermal Site
Kilauea Middle East Rift Zone

Data from the 1985 Puna Geothermal Area Biotic Assessment Report
Prepared for the Hawaii State Department of Planning and Economic Development
by the Department of Botany, University of Hawaii at Manoa

The Pro-Geothermal Alliance
invites to you to an
informational session on

**GEOTHERMAL INDUSTRY
DRILLING TECHNOLOGY
AND SAFETY**

with
Gerald M. Hamblin
District Drilling Superintendent
UNOCAL Geothermal Division

at 4:00 p.m.
Friday, November 15, 1991
Kapolei Room, 6th Floor
James Campbell Building
828 Fort Street Mall

UNOCAL is the world's largest producer of geothermal energy. The company supplies natural steam to power more than 1.7 million kilowatts of electrical generating capacity in the United States and the Philippines. For more than 25 years, Unocal has pioneered new technology in drilling, production, and reservoir engineering of geothermal resources. Unocal is also exploring geothermal resources in Indonesia and other Asian, African and Latin American countries.

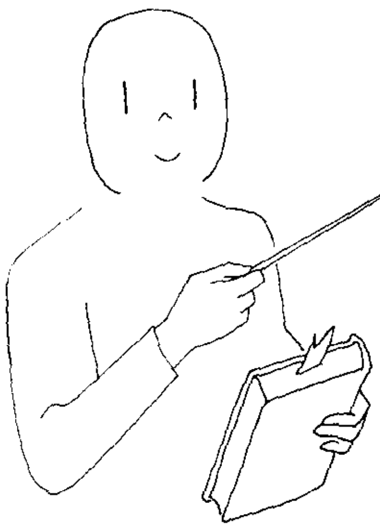
GERALD M. HAMBLIN, District Drilling Superintendent for Unocal's Geothermal Division, oversees Unocal's domestic drilling operations and international exploration projects. His primary responsibility is to ensure safe and environmentally acceptable operations. His 14 years of experience in drilling operations covered projects in California, Nevada, Idaho, New Mexico and Utah. He also has been involved in projects in Indonesia and the Philippines.

Pupus and refreshments will follow. Please respond by calling Jan Kadooka at 544-3212.

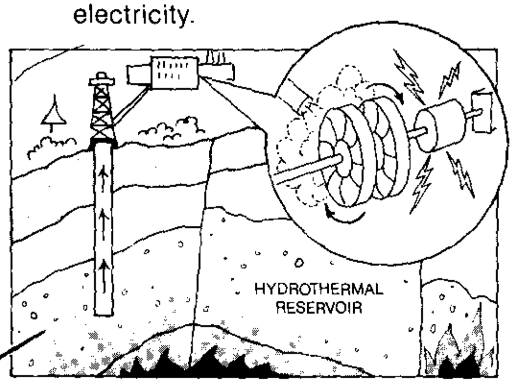
There are
4 BASIC KINDS OF GEOTHERMAL ENERGY.

❶ HYDROTHERMAL ENERGY
is being used today to produce electricity and for direct heating.

Reservoirs of hot water and/or steam are trapped in fractured rock or sediment in the earth's crust. There are 2 kinds of hydrothermal wells:



DRY STEAM ("hot steam") WELLS
To release the steam from the reservoir, a deep hole is drilled and a pipe is inserted. After solid particles are filtered out, the steam is used to turn the blades of a turbine and generate electricity.



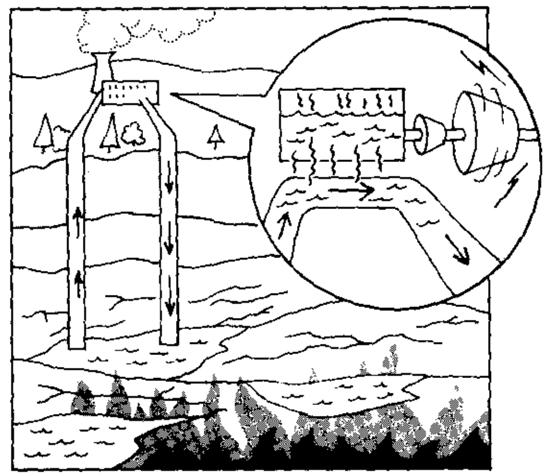
- Dry steam is the most widely used source of geothermal energy for electrical generation. However, the number of potential dry steam sites is very limited.
- It's the type of power harnessed at The Geysers in California and at Lardarello, Italy.

HOT WATER WELLS
The water and steam found in these wells can be used to make electricity in 1 of 2 ways:

❶ THE STEAM IS SEPARATED FROM THE WATER in a special vessel and is then used to drive a turbine. The water that remains is usually injected back into the earth. (This is known as the "flash" method.)

❷ THE HOT WATER IS USED TO HEAT ANOTHER LIQUID that has a lower boiling point. The liquid turns into a gas, which is used to turn a turbine. The original hot water is returned to the earth. (This is called the "binary cycle" method.)

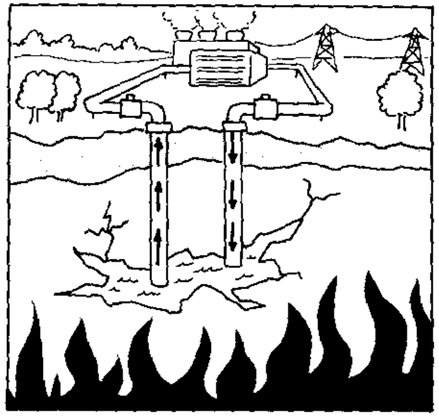
Hot water wells are a growing source of geothermal energy. They are in use today in Southern California, Nevada and along the Pacific Rim.



Learn about other types of geothermal energy being developed for possible future use . . .

❷ HOT DRY ROCK GEOTHERMAL

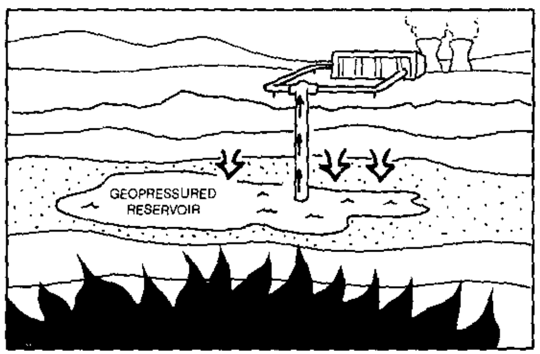
In some areas, magma is close enough to the earth's surface to heat rock containing little or no water.



HOT DRY ROCK AREAS ARE THE MOST ABUNDANT and widely distributed source of geothermal energy. However, more research is needed to determine if these areas can become an economical source of energy.

❸ GEOPRESSURED RESERVOIRS

These contain a mixture of water and methane (natural gas). Geopressured reservoirs are found in sandstone that's sandwiched between layers of rock.



IN THE U.S., some of the largest geopressured reservoirs are found along the Gulf Coast of Texas and Louisiana.

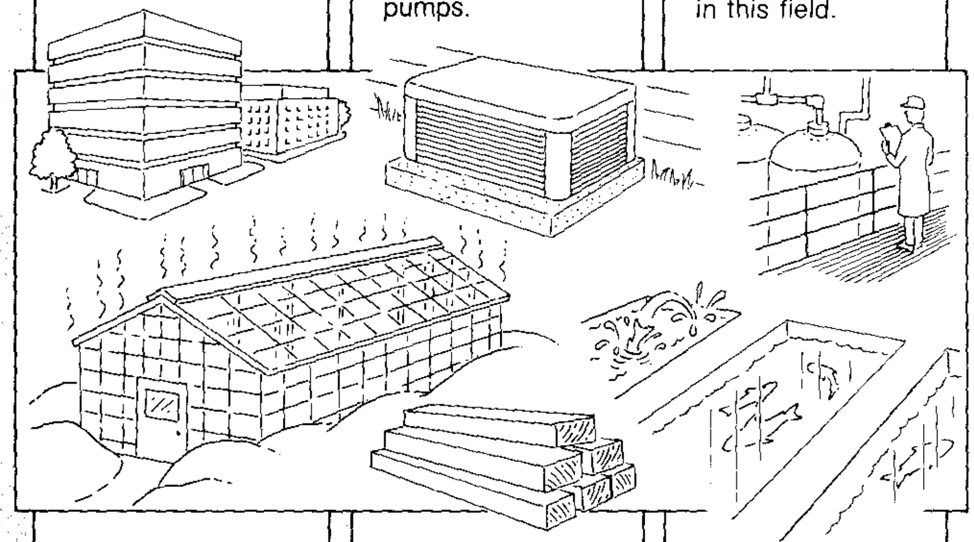
AT LOW AND MODERATE TEMPERATURES

(less than 350°F), it can be used for:

HEATING
Geothermal energy can be used to heat a single structure (space heating) or several buildings in the same area (district heating).

HEAT PUMPS
Heat pumps can be used for space heating and cooling. Pumps that use geothermal energy are much more efficient than air-source heat pumps.

FOOD PROCESSING
Preheating, cooking and drying foods, and sterilizing utensils and equipment are only a few ways to use geothermal energy in this field.



GREENHOUSES AND SOIL WARMING
Geothermal heat can extend the growing season in cooler climates.

PREPARING WOOD PRODUCTS
Geothermal energy can heat kilns to dry wood for lumber, paper, etc.

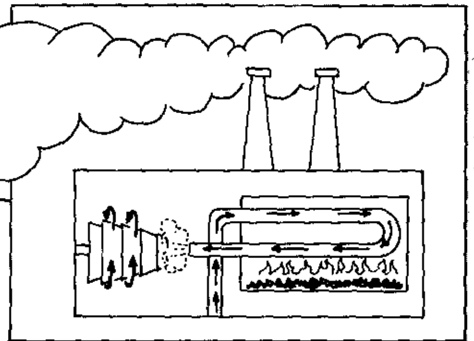
RAISING FISH
Waters warmed by geothermal heat can expand the areas where fish farming is profitable.

GEOTHERMAL ENERGY IS USED IN 2 WAYS

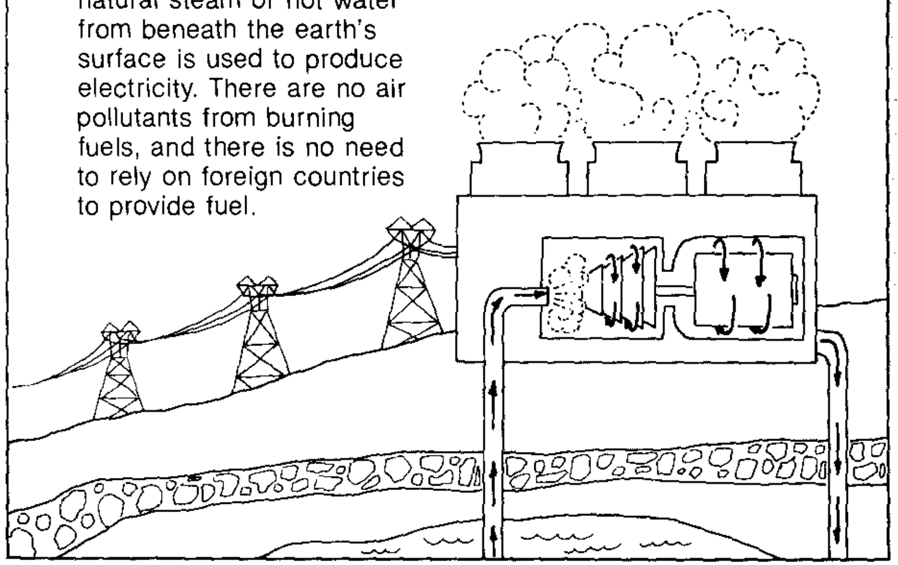
AT HIGH TEMPERATURES,

it can be used to generate electricity.

IN MOST ELECTRIC PLANTS,
a fuel (coal, oil or natural gas) is burned to heat water until it turns to steam. This steam is then used to turn a turbine and make electricity.



IN GEOTHERMAL PLANTS,
natural steam or hot water from beneath the earth's surface is used to produce electricity. There are no air pollutants from burning fuels, and there is no need to rely on foreign countries to provide fuel.

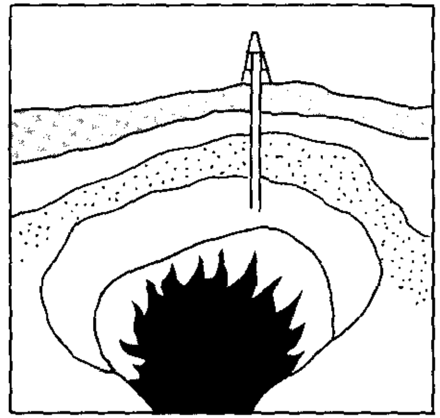


Geothermal power plants are an extremely reliable source of electricity.

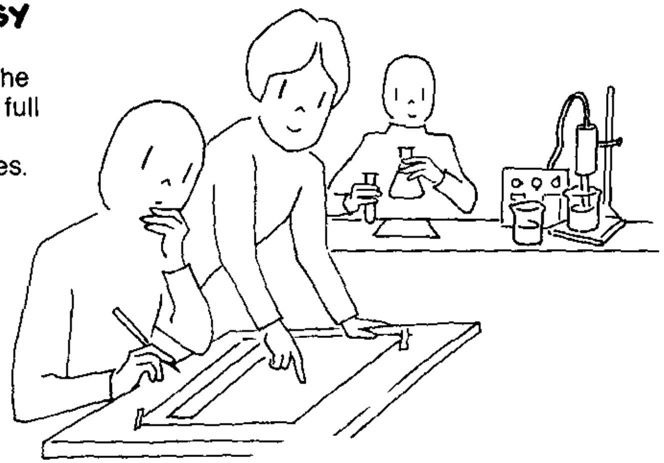
4 MAGMA

Magma is very hot molten rock found below the earth's crust.

IN CERTAIN LOCATIONS
in the western continental U.S., Alaska and Hawaii, it may be possible to extract heat from the magma.



IMPROVED TECHNOLOGY
and continued research are the keys to taking full advantage of these resources.

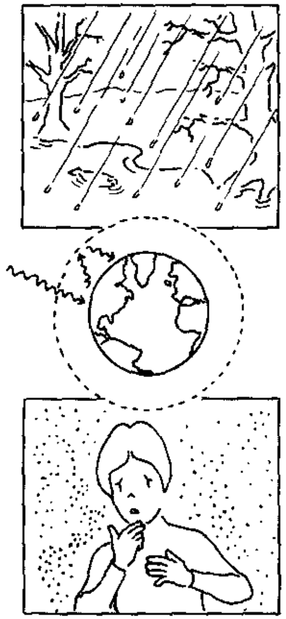


BENEFITS OF GEOTHERMAL ENERGY

Geothermal energy offers some important advantages. For example:

THERE'S LITTLE POLLUTION

That's because there's no burning of fossil fuels at geothermal electric plants.



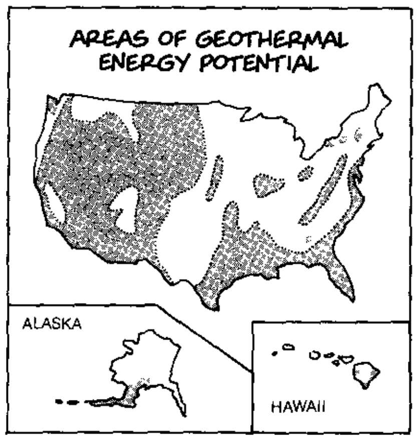
HOWEVER, PLANTS THAT DO BURN FOSSIL FUELS

produce large amounts of carbon dioxide and other pollutants that have been linked to problems such as:

- ACID RAIN, which may harm fish and other forms of life in rivers, lakes and streams. It may also damage forests and crops, and erode statues, paint and building materials.
- THE GREENHOUSE EFFECT, which may lead to a dramatic warming of the earth's surface temperature. Such a warming could affect plant life, climate, water resources and more.
- POOR AIR QUALITY, which affects us all, but can be especially harmful to people with heart and lung problems.

THE UNITED STATES

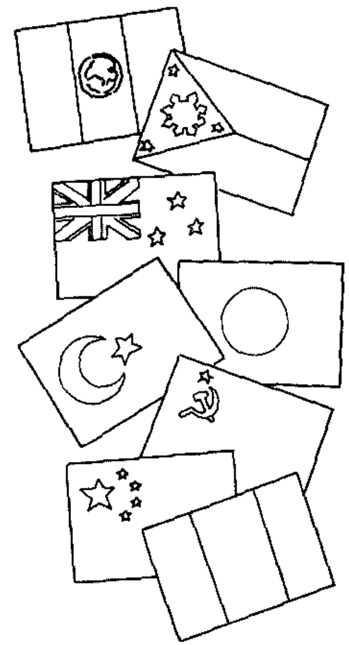
- "The Geysers" in Northern California is the largest geothermal electrical power complex in the world. Other plants are located in Utah, Hawaii, Nevada and Southern California (where the use of geothermal energy is rapidly growing).
- Boise, Idaho, is one of the leaders in geothermal heating. The city began using geothermal energy to heat homes in the 1890s. Klamath Falls, Oregon is another city that uses geothermal heat to warm homes, businesses, a hospital and a college.
- Research and development on other geothermal projects are in progress.



OTHER COUNTRIES

For example:

- Mexico
- the Philippines
- New Zealand
- Japan
- Turkey
- the Soviet Union
- China
- France.



Geothermal power --

AT HOME AND AROUND THE WORLD

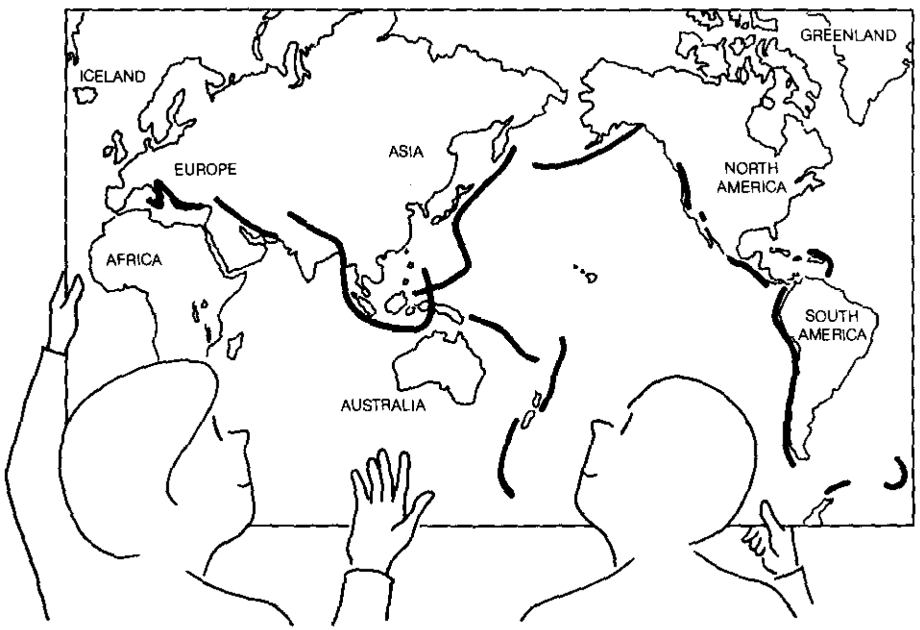
Many countries are using or exploring geothermal energy. They include:

ITALY

The Italians were the first to see the potential for using geothermal energy to generate electricity. They built a generator at Lardarello in 1904, in a geothermal area that is still producing today.

ICELAND

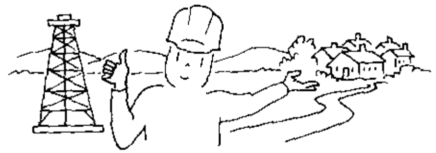
The most extensive use of geothermal heating in the world is on the volcanic island, Iceland. Most of the island's homes and businesses are heated geothermally. Geothermal energy is also used to generate electricity, and it's used in industry, too.



GEOTHERMAL ENERGY RESOURCES are most prominent along the "Ring of Fire." This is where several sections (plates) of the earth's crust meet. It's where most of the world's volcanoes are located, and most earthquakes occur.

A LIMITED AREA IS AFFECTED

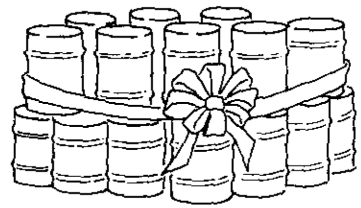
A geothermal operation takes place in a confined area. Also, there's no need for mining or transportation of fuel or wastes over long distances.



IT SAVES FOSSIL FUELS

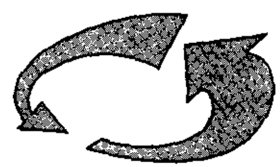
For example, the use of geothermal energy saves millions of barrels of oil each year! This means:

- less dependence on foreign sources for fuel
- fossil fuels can be saved for other purposes, such as fuel for transportation.



IT'S "RENEWABLE"

Unlike fossil fuels, geothermal resources can replenish themselves over time, and with careful management.



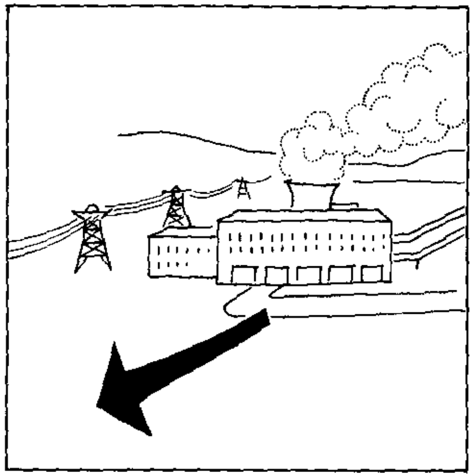
IT'S A RELIABLE SOURCE OF ENERGY

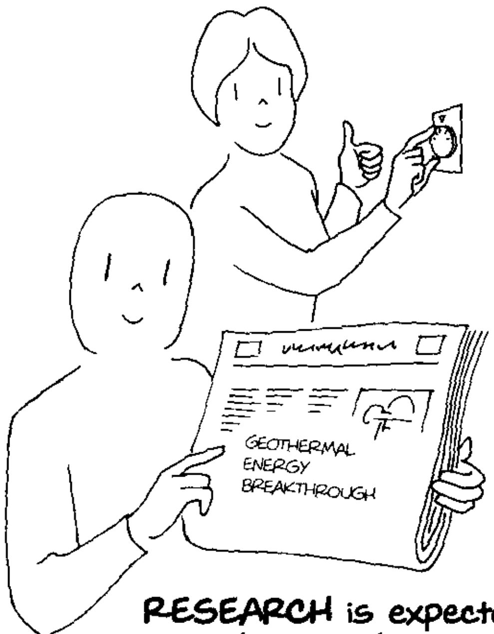
Geothermal energy sources aren't affected by changing weather conditions that affect other renewable energy sources, such as solar and wind power.

THE FUTURE
of geothermal energy looks bright.

THE BENEFITS ARE GREAT

- Geothermal energy can be used directly at low and moderate temperatures (for heating and many other purposes). And, it can be used indirectly at high temperatures (to produce electricity).
- It's a "clean," reliable source of energy that can help save vital fossil fuels.
- Local communities can benefit economically from the use of geothermal energy.



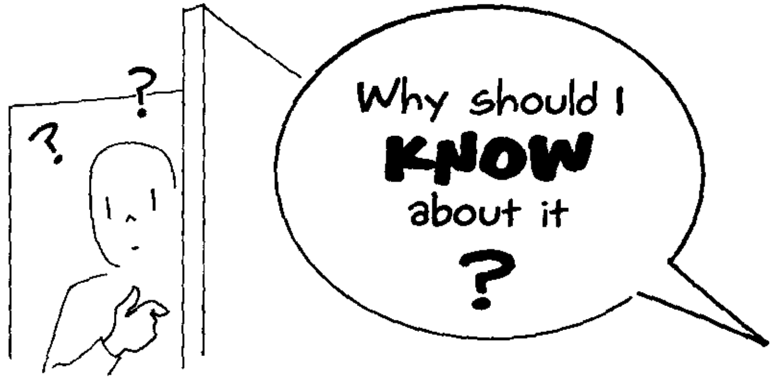


SOME CHALLENGES DO EXIST

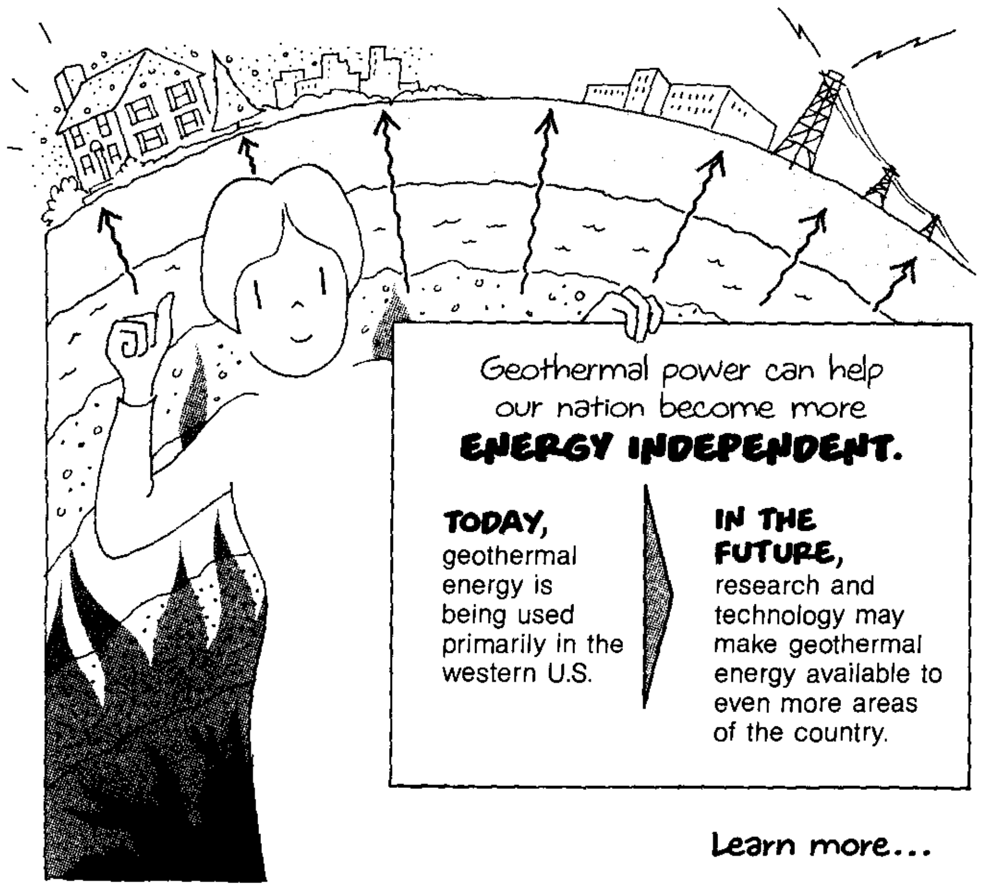
For example:

- Improved technology is needed to make some types of geothermal energy more economical.
- Careful management of geothermal resources is essential to ensure they're not quickly depleted.

RESEARCH is expected to lead to new procedures and systems that expand the use of geothermal energy.



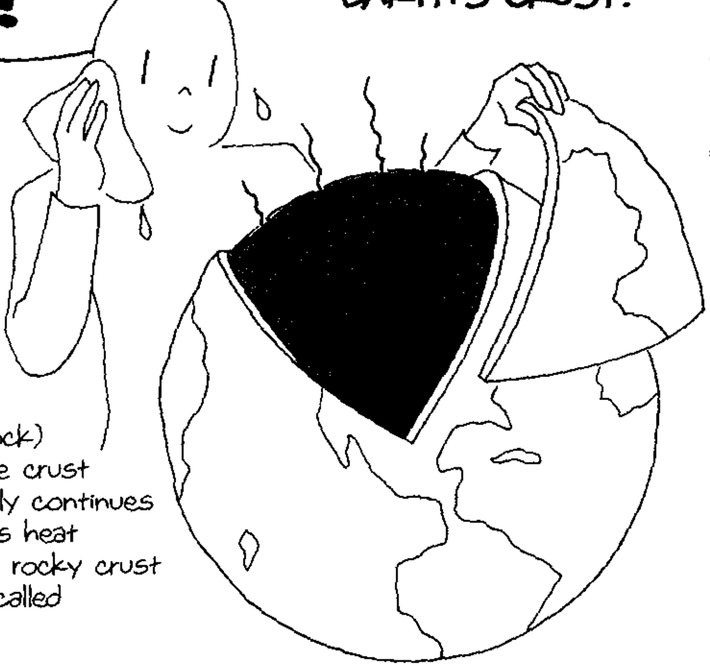
Because this vast source of energy can be put to use to help meet our energy needs.



Learn more...

What is GEOTHERMAL ENERGY?

It's HEAT ENERGY that comes from BENEATH THE EARTH'S CRUST.



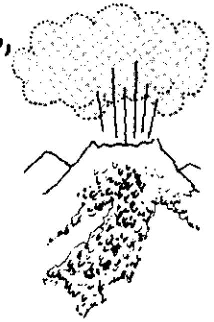
THE YOUNG EARTH was a fiery ball of liquid and gas. As it cooled, an outer crust formed over the liquid core.

MAGMA (molten rock) was left between the crust and core. As it slowly continues to cool, the magma's heat is transferred to the rocky crust above. This heat is called geothermal energy.

VISIBLE FORMS of geothermal energy include:

HOT SPRINGS OR NATURAL STEAM, when hot water or steam from within the crust surfaces.

VOLCANOES, when magma itself surfaces as lava.



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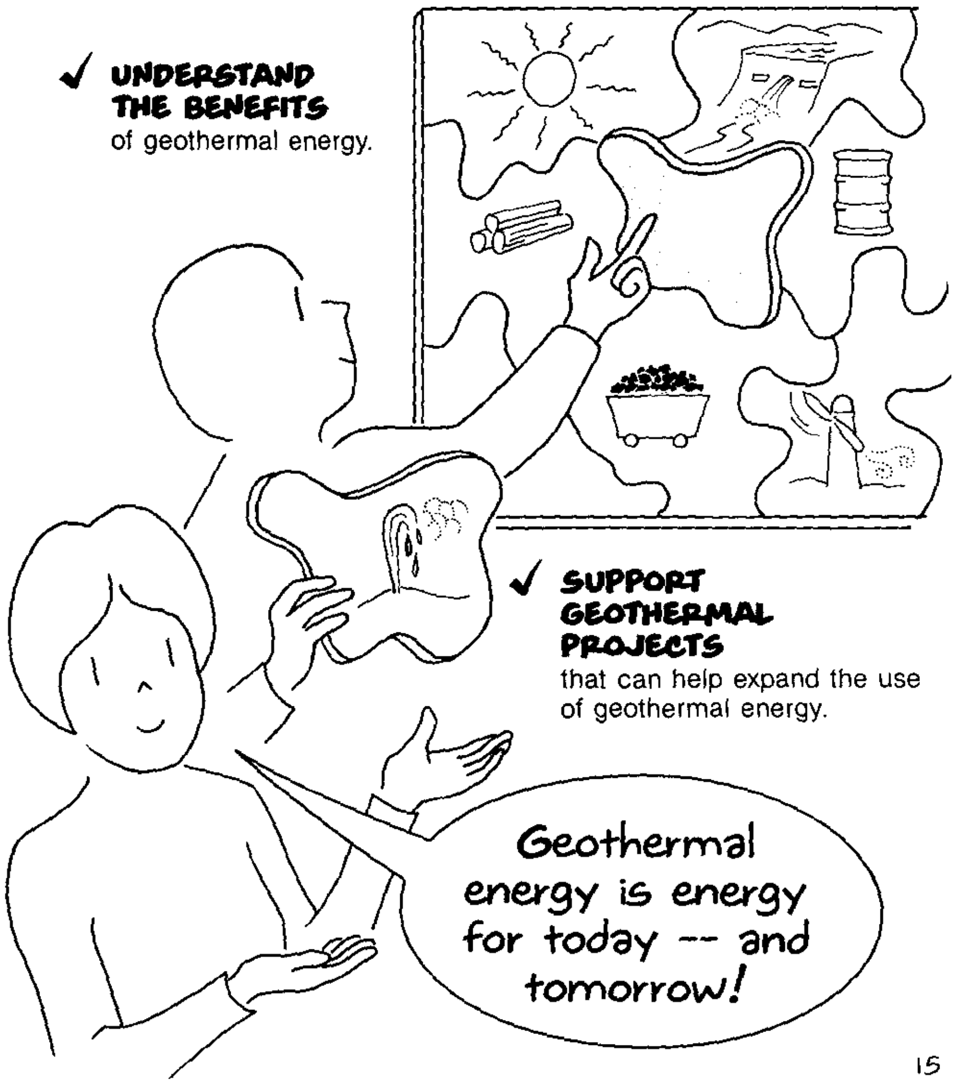

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ABOUT GEOTHERMAL ENERGY

A Lot.

Geothermal, A Proven Technology

Geothermal energy is not new. The technology is time tested and steadily improving. The techniques for drilling and converting geothermal energy into electricity have been steadily evolving since the early 1900s. Today over 250 geothermal power plants are operating in 21 countries including Italy, the Philippines, Japan, Mexico and the United States.

Geothermal power is reliable, renewable and clean. It is Hawaii's Great Energy Opportunity.

What to Do

—If you think geothermal will benefit Hawaii—

* Write letters to government leaders and newspapers explaining your point of view.
* Talk to your friends and neighbors.
* When you read or hear erroneous information about geothermal power, correct it yourself or let us know so we can.
* Join the ProGEO Alliance and help us communicate the facts effectively.
* Communicate the benefits to your co-workers and employees.

ProGEO The Pro-Geothermal Alliance
737 Bishop Street, Suite 2880
Honolulu, Hawaii 96813
Ph: (808) 523-8808 / Fax: (808) 521-6141

What's So Hot About Geothermal

?

Type of Energy	Environmental Effects	Reliability	Availability in Hawaii	Renewable	Proven Large Scale Technology
Oil	–	+	–	–	+
Coal	–	+	–	–	+
Hydropower	+	+	–	+	+
Biomass	–	+	+	+	+
Wind	+	–	+	+	–
Photovoltaic	+	–	+	+	–
Solar Thermal	+	–	+	+	–
Nuclear	–	+	–	–	+
OTEC	+	+	+	+	–
Geothermal	+	+	+	+	+

HOW GEOTHERMAL COMPARES -- This chart graphically illustrates the comparative pluses and minuses of various alternative energy sources. When compared to other alternatives in five key areas, Hawaii's geothermal energy gets good marks.

Hawaii's Quest for Alternate Energy

The 1973-74 Arab oil embargo stranded Hawaii without enough fuel. The shortage created long gas lines and soaring energy costs. As a result, the state government decided to search for and develop alternative energy sources to make us less dependent on imported sources. Since then, Hawaii has experimented with a variety of energy technologies. When the pluses and minuses of the various technologies available today are compared, geothermal shows up as the most feasible and responsible way for Hawaii to begin reducing its heavy (90%) dependence on imported fuels. In fact, the State Energy Functional Plan targets geothermal as our largest, near-term source of alternate energy.

Why Is Geothermal So Important?

First of all, the world's oil supply is a depletable resource and worldwide consumption continues to grow. In Hawaii, we have a "homegrown" resource with geothermal. With it we would not be as dependent on imported fuel to power our electrical generation system. There are state-designated zones on the Island of Hawaii that have underground reservoirs of water heated by magma to temperatures as high as 600 degrees Fahrenheit. The steam from a geothermal reservoir can be used to produce electrical energy in large quantities.

'OGEO The Pro-Geothermal Alliance • 737 Bishop Street, Suite 2880 • Honolulu, Hawaii 96813
Phone: (808) 523-8808 • Fax: (808) 521-6141

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DIV. OF WATER & LAND DEVELOPMENT

October 10, 1991

Mr. Manabu Tagomori
Deputy Director
Water and Land Development Division
Department of Land and Natural
Resources
1151 Punchbowl Street
Honolulu, Hawaii 96813

Dear Manabu:

The Pro-Geothermal Alliance was organized to provide current and factual information to the public related to the development and use of Hawaii's geothermal energy. We have attempted to disseminate this information through various means, such as briefings.

We believe that government representatives such as yourself may find it useful to hear from an expert in geothermal drilling in light of the concerns surrounding the June 12 incident at the Puna Geothermal Venture well. Mr. Gerald Hamblin, District Drilling Superintendent for Unocal's Geothermal Division, will speak on the state of the industry's technology and its safety record.

This will be a small, informal briefing for government officials only to ensure that your questions and concerns are fully discussed. The following are the details of the briefing:

Friday, November 15, 1991
4:00 p.m.
Kapolei Room, 6th Floor
James Campbell Building
828 Fort Street Mall

Pupus and refreshments will follow. Parking at the Liberty House downtown garage, off Bethel Street, will be fully validated. Please respond by calling Jan Kadooka at **544-3212** by Friday, **November 1.** We hope you will be able to attend.

Sincerely,

Clinton R. Churchill
Chairman, Pro-Geothermal
Alliance

01001900/K10065

Geothermal: Hawaii's Great Energy Opportunity

The Pro-Geothermal Alliance
invites to you to an
informational session on

GEOTHERMAL INDUSTRY DRILLING TECHNOLOGY AND SAFETY

with
Gerald M. Hamblin
District Drilling Superintendent
UNOCAL Geothermal Division

at 4:00 p.m.
Thursday, November 15, 1991
Kapolei Room, 6th Floor
James Campbell Building
828 Fort Street Mall

IOCAL is the world's largest producer of geothermal energy. The company supplies ural steam to power more than 1.7 million kilowatts of electrical generating capacity in United States and the Philippines. For more than 25 years, Unocal has pioneered new hnology in drilling, production, and reservoir engineering of geothermal resources. ocal is also exploring geothermal resources in Indonesia and other Asian, African and tin American countries.

RALD M. HAMBLIN, District Drilling Superintendent for Unocal's Geothermal vision, oversees Unocal's domestic drilling operations and international exploration jects. His primary responsibility is to ensure safe and environmentally acceptable erations. His 14 years of experience in drilling operations covered projects in California, vada, Idaho, New Mexico and Utah. He also has been involved in projects in Indonesia l the Philippines.

pus and refreshments will follow. Please respond by calling Jan Kadooka at 544-3212.

Let's keep energy focused on safe geothermal

VIEW POINT

By Clint Churchill

THE June 12 blowout at Puna Geothermal Venture's (PGV) site has halted geothermal activity on the Big Island and reignited the debate over the merits of continuing geothermal exploration in Hawaii. The welfare of Hawaii residents must always come first and we must do everything possible to make sure that geothermal is developed safely.

But now, more than ever, with our energy needs growing at a steady rate, it is imperative that our decisions regarding geothermal exploration are based on a sensible, safe and long-term approach to solving our energy needs — not on isolated incidents.

The PGV incident was a traumatic event for residents, the state and county, and the developer. But it does not change the fact that Hawaii is burdened by a 90 percent dependency on fossil fuel for energy. The price increases experienced during the Persian Gulf War dramatically underscored Hawaii's vulnerability.

While other alternative energy sources could alleviate some of our need for oil, some sources like wind, solar and OTEC are relatively new technologies which are not capable of providing a firm source of power, and others like biomass are as environmentally harmful as oil or coal.

Geothermal, on the other hand, is an 80-year-old technology used in 21 countries. It's clean, reliable and a proved technology that is steadily improving. It's also here for the long haul. According to a recent progress report by Hawaiian Electric Co., with imported geothermal power as a viable energy source by the turn of the century, it could help reduce Hawaii's dependence on oil for electricity from 90 percent to less than 32 percent by the year 2010.

In addition to Hawaii's heavy dependence on fossil fuel, we also need to realize that our energy needs will continue to grow. More people and more businesses mean more electricity. Conserving energy is an important alternative but, unfortunately, conservation cannot significantly affect Hawaii's growing energy needs. Rolling blackouts on the Big Island are only some of the effects of an energy system that is unable to keep up with growth.

The questions remain: Do we build more fossil fuel power plants which will increase our dependency on oil and our reliance on unstable sources for electricity? Do we continue to fund the construction of coal-burning plants, each of which releases 63 percent more carbon dioxide than oil does into the atmosphere?

Or do we continue to seek a clean, renewable, reliable source of energy available right in our own backyard?

As stated earlier, the welfare of our residents should always be of paramount concern. It is also important not to sacrifice our future. Geothermal can be developed safely. It's been proved time and time again worldwide. We must continue to move forward in a safe, responsible manner and not let this precious resource slip through our fingers.

Clint Churchill is chairman of the Pro-Geothermal Alliance.

HONOLULU STAR-BULLETIN
October 10, 1991

Star-Bulletin
October 25, 1990

Heated geothermal debate can end in harmony

VIEW POINT
By Clinton R. Churchill

WHAT'S so hot about geothermal? A lot. Geothermal energy development has sparked hot debate in Hawaii, but this is not the first time Hawaii has witnessed the turmoil that surrounds a new development concept.

The Big Island endured a similar experience when plans for an observatory atop Mauna Kea were first proposed in 1967. What would the project and its subsequent daily operations do to the delicate balance of the mountaintop ecosystems? Today Mauna Kea Observatory stands as one of the premier working environments for scientists from around the world, proving harmony can be achieved between man, technology and nature.

The same harmony can be achieved with the development of geothermal energy.

Geothermal can be developed safely and responsibly. The technology has been proved in 21 countries. Development can be entirely compatible with the needs of man and nature. It is unfortunate that everyone does not have the opportunity to visit geothermal sites in California and Nevada. Testimony from those who have seen these plants is almost universal: "What's the big deal?"

Geothermal makes environmental sense. It is a clean alternative that uses natural steam to generate electricity. On the other hand, burning oil or coal to make steam to generate electricity produces large amounts of carbon dioxide, a major contributor to global warming, and other pollutants.

Geothermal is reliable and renewable. It is the only local source of natural energy that can produce electricity in large quantities 24 hours a day, 365 days a year. Geothermal is renewable when managed properly. Hawaii's rainfall and volcanic heat create extremely favorable conditions that give geothermal the potential to become Hawaii's greatest energy opportunity.

We cannot afford to ignore a resource that will give us local control over a local source of energy.

The effect of a Middle East crisis on the price of oil in Hawaii is not a new phenomenon. In 1973-74 and in 1979, the Arab oil embargo and Middle East wars resulted in the state's decision to encourage research and development of alternate energy sources such as geothermal. Geothermal development has since gone through more than a decade of public discussion with numerous public hearings, legislative discussion, contested case hearings, and court cases which dealt with issues such as Pele worship, the land exchange, environmental issues and proper permitting. All of the cases resulted in decisions supporting geothermal development.

While geothermal development was stalled by these proceedings, Hawaii's population continued to grow and our energy situation has become more precarious. Without new energy sources such as geothermal, the growth in electricity usage over the next 20 years will result in Hawaii having to import a total of 11 million barrels of residual oil per year. A 500 megawatt geothermal project can eliminate the burning of more than seven million barrels of oil per year. The savings are real in terms of barrels of oil and dollars and cents.

Despite claims to the contrary, federal law does not require that the costs of geothermal energy be tied permanently to the price of oil or the utilities' "avoided cost." This will be a matter of negotiation between the developers and the electric utilities.

For example, the cost of energy produced by the new coal-fired plant at Campbell Industrial Park is pegged to inflation and not the price of oil. Geothermal can provide us with an opportunity for real savings and energy independence.

Some argue that the geothermal plants and the cable project could cost $4 billion and that this will be an unreasonable burden to the rate payer. They fail to point out that the cost of burning oil every day, every year will be at least $4 billion over the same time frame. The current crisis in the Middle East recently caused oil prices to jump to $40 per barrel. At this cost level, over 30 years, a project generating 500 megawatts of geothermal electricity will avoid burning $8.4 billion of oil.

Those who assert that conservation is the simple answer to Hawaii's energy problems should realize that, while electricity usage in Hawaii is growing at 3 percent per year, the most aggressive and successful conservation efforts in other states have reduced rates of growth by 1 percent per year.

Even then, the most effective energy savings resulted from efficiencies in heating and cooling systems not widely used in Hawaii, and economic incentives for utilities, which do not apply to Hawaii. Obviously, Hawaii should pursue every practical energy option: from conservation through the wide array of viable alternative energy sources now underdevelopment or yet to be discovered. We simply cannot afford to ignore any energy alternative.

A recent Star-Bulletin/KGMB News poll indicated 70 percent of those polled support geothermal. It is heartening to know that more and more people are getting the facts and recognizing the value of geothermal as a dependable, clean and renewable source of Hawaii-produced natural energy.

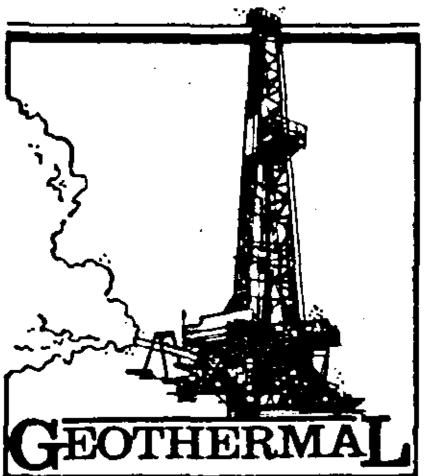
Clinton R. Churchill is chief executive officer of Campbell Estate and chairman of the Pro-Geothermal Alliance.

Hawaii Tribune-Herald
May 30, 1990

What lies beneath surface will decide geothermal future

Editor's note: Last month, the Tribune-Herald's geothermal reporter, Dave Harada-Stone, travelled to Southern California to see several geothermal plants and how they've fit in with their surrounding communities. Besides touring the plants, Harada-Stone also met with local officials to see how the promises made when geothermal development was first proposed have jibed with the reality. The following is the final in a three-part series.

By Dave Harada-Stone
Tribune-Herald



The record in Southern California

EAST MESA, Calif. — Geothermal Resources International and Ormat Energy Systems have invested hundreds of millions of dollars in hardware to turn the geothermal fluids beneath this desert area into electricity for sale to customers hundreds of miles away.

Between them, the two companies have in the past decade built six power plants, for a combined net output of about 131 megawatts, and drilled dozens of wells thousands of feet into the ground.

But it isn't so much the tons of heavy machinery, miles of pipeline or rooms full of high-tech control equipment that will determine the long-term success of the two companies' ventures in the East Mesa, and others like them elsewhere in California's Imperial Valley.

That will depend on what lies beneath.

Experts say the geothermal resource beneath the East Mesa and other so-called Known Geothermal Resources Areas, or KGRAs, is vast. But just how vast is a mystery.

Paul Sweeny, geothermal program manager for the California Regional Water Control Board, says there is probably a limit to how much development East Mesa and other KGRAs can take. While the six plants now operating in East Mesa — and the eight located elsewhere in the valley — may well continue producing for as long as 30 years, the potential for further development may be limited, Sweeny told the board recently.

"The problem in East Mesa is there are too many straws in one glass of water," he said. "The more people you have working on a fixed resource, the faster it will go away."

How fast is anyone's guess.

In the Geysers area of Northern California, the guesses proved to be way off.

Under development since the 1960s, the Geysers geothermal field is the world's largest, boasting some 1,900 megawatts of generating capacity — nearly five times the 400 megawatts installed in the valley.

HAWAII TRIBUNE-HERALD
May 30, 1990
Page 3
Circ: 23,145

California uses comic books to tout geothermal

By Dave Harada-Stone
Tribune-Herald

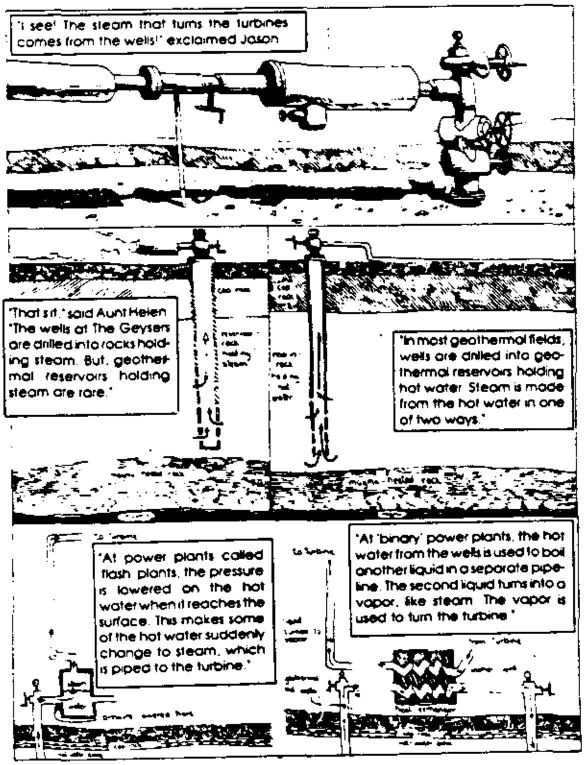
EL CENTRO, Calif. — The California Department of Conservation's Division of Oil and Gas is bullish on geothermal energy, and it wants to get across to residents what officials see as the merits of the alternate energy technology.

Apparently subscribing to the theory that simpler is better, the division has capusulized what it wants the public to know about geothermal in the form of a comic book, titled, simply enough, "Geothermal in California."

Though prepared for 4th to 9th graders, the book is touted as providing a "useful overview" for adults as well.

The comic book tells the story of Lisa and Jason and their trip to the Geysers area of Northern California to vist Aunt Helen and Uncle Frank.

Once there, Helen and Frank treat the children to a tour of the area's geothermal developments, including the largest network of geothermal power plants in the country.



EASY READING — The California Department of Conservation's Division of Oil and Gas has capusulized what it wants the public to know about geothermal energy in a comic book, part of which is shown above.

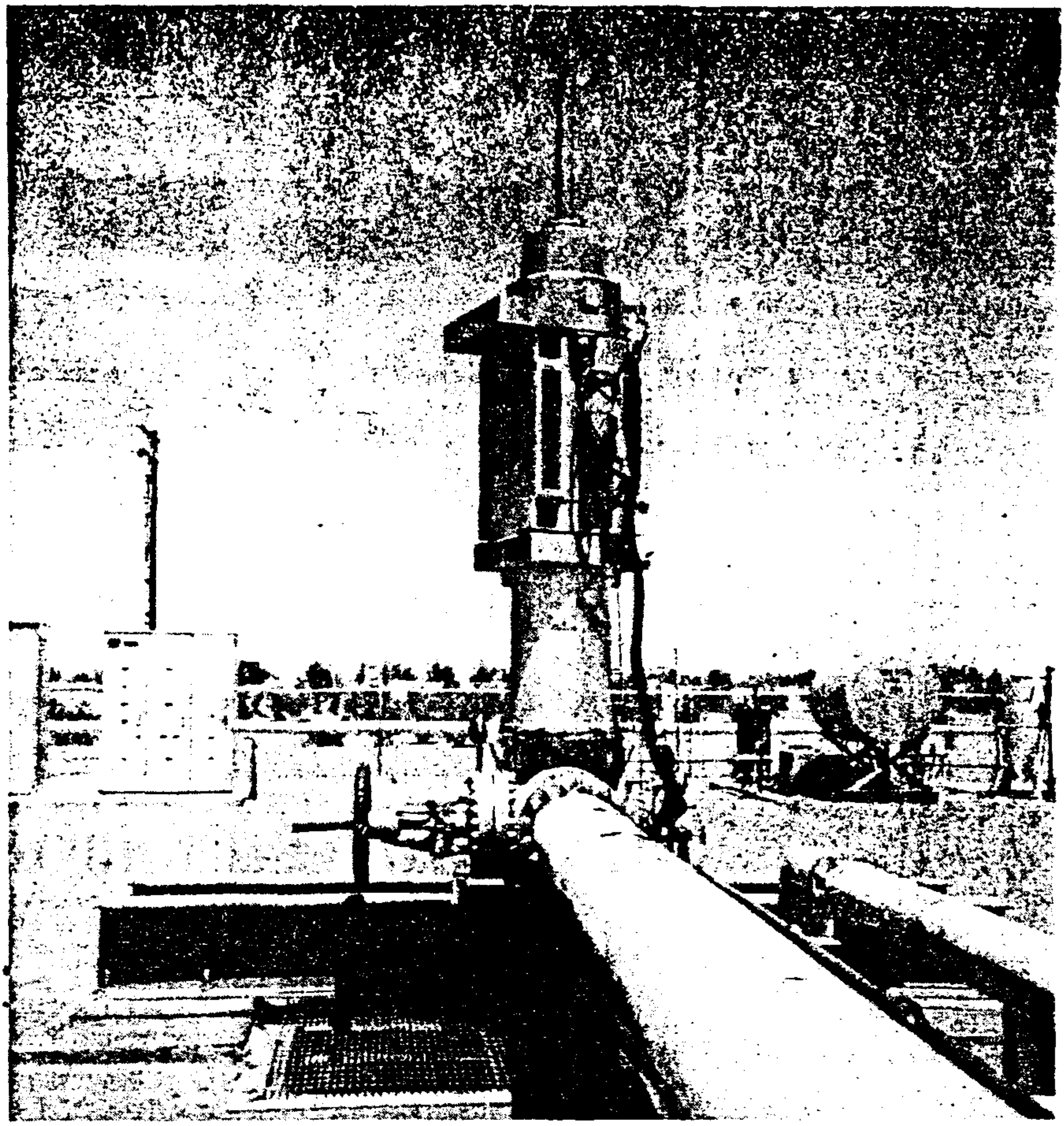
Using comic book imagery and simple language, the book explains the mechanics behind the extraction of geothermal steam and its conversion to power.

Environmental issues are covered in somewhat less detail. A brief mention is made of the environmental study and permitting process, but there is no mention of such subjects as emissions or solid and liquid wastes.

Nor is there much discussion of the depletion of the geothermal resource, a problem that has dramatically reduced power generation at the Geysers.

The comic introduction to geothermal conculdes with a rather upbeat assessment of the technology by Aunt Helen:

"We're still learning how to use geothermal energy. There's so much of it all over the world. We could be using much more than we do. Geothermal energy has a great future."



—T-H photo by Dave Harada-Stone

TAPPING IN — A geothermal well operated by Ormat in the Imperial Valley's East Mesa area. While there appears to be enough of a resource beneath the valley to support existing development, officials are uncertain how much more development the geothermal reservoir can support.

But 400 of those megawatts have been idled because the reservoir upon which the area's power plants draw is running out of steam.

Pacific Gas & Electric, which relies on the Geysers for 10 percent of its generating capacity, had seen its production drop by 22 percent, or about 300 megawatts, as of late last year.

At a hearing last September before the California Energy Commission, PG&E noted its steam suppliers were projecting an average annual rate of decline of 10 to 14 percent. The declines have varied widely depending on the location of the geothermal wells.

A spokesperson for Unocal Corp., developer of most of the region's geothermal wells, told the commission the decline is

See FUTURE, Page 3

FUTURE: Resources limited?

From Page 1

likely due to a combination of factors, including the accelerated decline of individual wells; increasing "interference," or the diversion of steam from an existing well into a new one; the discovery of corrosive steam in the northern portion of the Geysers field, thus reducing the potential steam supply; and higher levels of non-condensable gases in the steam.

PG&E has modified its equipment at the Geysers to make better use of the steam it does get out of the ground. Other potential remedies implemented or under study include reinjection of geothermal fluids to "recharge" the underground reservoir — a measure taken by virtually all geothermal developers in the Imperial Valley — and drilling additional and deeper wells.

Whatever the cause of and the answer to the apparent depletion of the Geysers resource, officials in the Imperial Valley are hopeful they can avoid a similar surprise here.

Given the relative youth of the Imperial Valley's geothermal fields — most of the development has taken place in the past five years — it's still too early to tell how long the resource may last, said Tim Boardman, geothermal district engineer for the California Division of Oil and Gas.

"You do expect you will have depletion in time," he said. "We are watching it very closely. Hopefully we can predict it a little closer (than in the Geysers)."

He noted that the Geysers field was developed before a lot was known about geothermal resources, "when they thought geothermal was a renewable resource."

He pointed out that the Geysers field remains hot. What's missing is the water from which the subterranean heat generates steam.

"We're reinjecting water at a high rate (in the Imperial Valley)," he said.

The resources in the two areas are also markedly different. While the 200-plus wells in the Imperial Valley tap a reservoir made up largely of geothermal brines, or hot, salt-laden fluids. The resource in the Geysers, is made up mostly of steam.

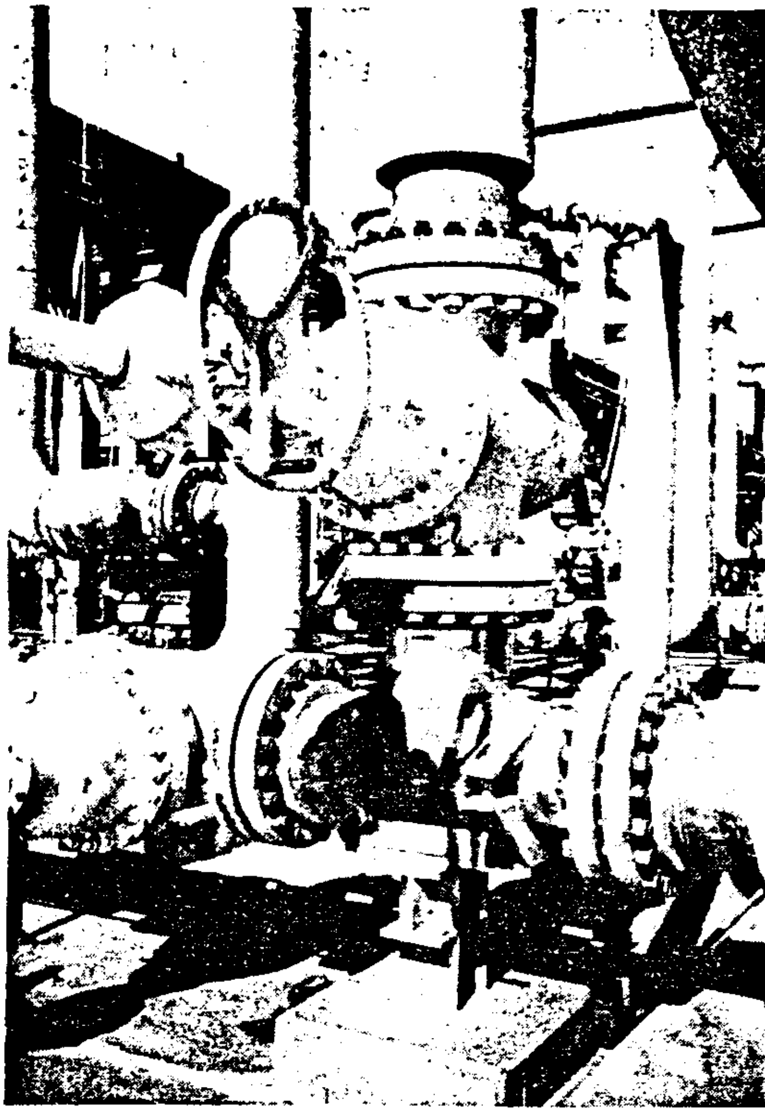
What the disappointments in the Geysers and the as yet limited experience in the Imperial Valley suggest for development in Hawaii is unclear.

Critics of geothermal development in Puna often point to the decline of the Geysers and suggest the same fate awaits geothermal energy on the Big Island. They have relied for support, in part, on testimony in 1982 by Robert Decker, then scientist in charge of the Hawaiian Volcano Observatory.

Speaking before the state Board of Land and Natural Resources, Decker said his estimates of the thermal resource beneath Kilauea Volcano indicated that extracting anything in excess of five megawatts from Kahaualea, then the site of a proposed geothermal development, would result in the depletion of the geothermal resource.

Other experts have said the geothermal resource beneath the volcano could sustain a much larger yield. And Decker himself, in his 1982 testimony, indicated the Big Island could probably meet its own electricity needs with geothermal, but might be depleting the resource should it export more than 50 to 100 megawatts of power.

"And I don't know how long it would take to deplete it," Decker added at the time. "It may take a couple hundred years. Of course, we mine our other resources, and they're depletable too."

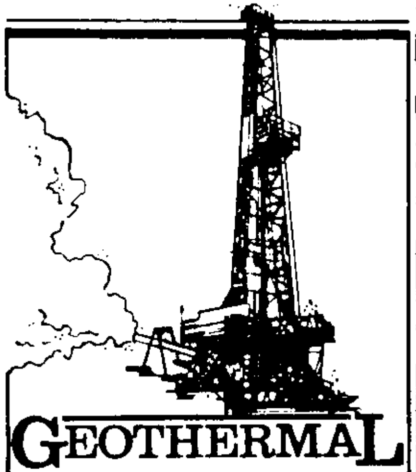


—T-H photo by Dave Harada-Stone

HEAVY DUTY PLUMBING — A jumble of piping and valves directs steam to the turbines of Unocal's Salton Sea Unit 3 power plant in California's Imperial Valley.

Hawaii Tribune-Herald, May 29, 1990

California's geo regulators have different concerns



The record in Southern California

Editor's note: Last month, the Tribune-Herald's geothermal reporter, Dave Harada-Stone, travelled to Southern California to see several geothermal plants and how they've fit in with their surrounding communities. Besides touring the plants, Harada-Stone also met with local officials to see how the promises made when geothermal development was first proposed have jibed with the reality. The following is the second in a three-part series.

By Dave Harada-Stone
Tribune-Herald

SALTON SEA, Calif. — This saltwater lake in the northern Imperial Valley is a tribute to the ability of humans to radically alter their environment — sometimes in ways they never foresaw.

At 374 square miles, the Salton Sea is the largest lake in California and the 10th largest in the United States (not including the Great Lakes). It is also an accident.

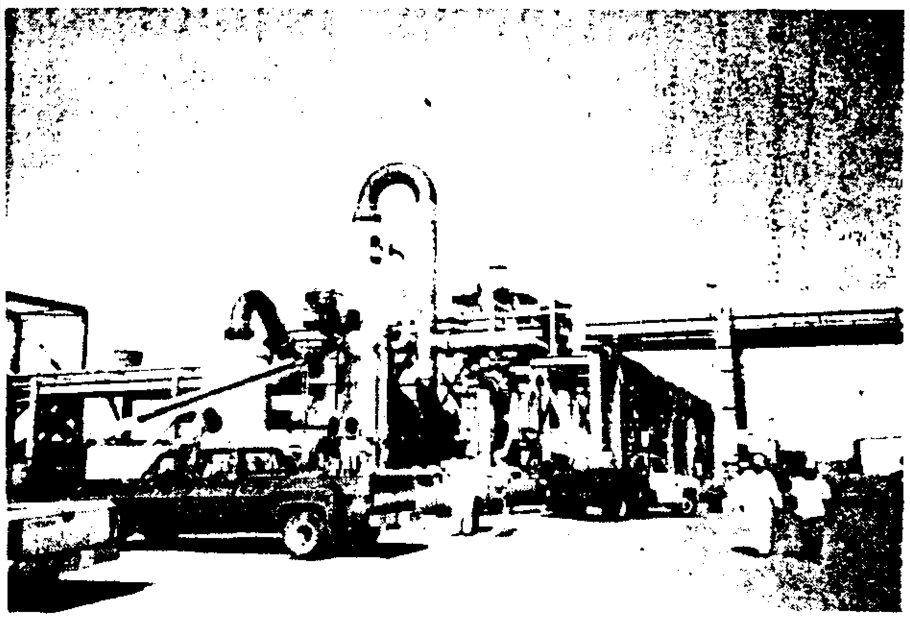
The lake was created near the turn of the century when engineers fiddling with the flow of the Colorado River diverted its waters, thus filling the trough, 227 feet below sea level, that was to become the Salton Sea.

Today, the sea is regarded as a recreational resource and parts of its banks are protected as a wildlife preserve.

The lake's southeast shore, meanwhile, is the site of the largest geothermal field in the valley, with six power plants generating nearly 200 megawatts of electricity to meet the power demands of the Los Angeles area.

State regulators recognize that not all of man's mistakes turn out as well as the Salton Sea did, and they say they're working full-time to make sure geothermal

See GEOTHERMAL, Page 6



—T-H photos by Dave Harada-Stone

SEASIDE — The Salton Sea, above, was created by accident early in the century when crews inadvertently diverted the waters of the Colorado River. Six geothermal plants are now on its shores. At left, Unocal's Salton Sea Unit 3 facility.

GEOTHERMAL: Valley has different woes

From Page 1

development here doesn't produce another environmental surprise.

The valley's geothermal developments have escaped the principal environmental curse of similar projects elsewhere, namely hydrogen sulfide. The noxious gas has an odor like that of rotten eggs and, at high enough levels, can cause eye and respiratory distress. At extremely high levels, hydrogen sulfide can cause death.

At the HGP-A facility in Pohoiki, hydrogen sulfide emissions prompted numerous complaints by nearby residents. Their experience has contributed significantly to the skepticism amoung Puna residents about the environmental promises made by Ormat Energy Systems, developer of the 25-megawatt Puna Geothermal Venture project in Pohoiki, and other developers.

In the valley, however, emissions have simply not been a problem, according to Harry Dillon of the Imperial County Air Pollution Control District.

"You can smell it if you get right up on the plants' cooling towers, but not at the fenceline," he said. "And our plants are pretty isolated."

Even without much effort at abatement, Dillon said, the valley's plants have no problem meeting California's ambient hydrogen sulfide limit of about 30 parts per billion, even with little or no effort at abatement.

A look at the numbers will indicate why.

Dillon estimates the hydrogen sulfide concentrations in the valley's resource at about 25 parts per million. Compare that with the Geysers field in Northern California, where the gas has sometimes been a problem, at 200-to-1,000 parts per million, and Hawaii, where composite data from the HGP-A well and three commercial test wells in Pohoiki put the hydrogen sulfide content at between 800 and 1,300 parts per million.

Hawaii developers have looked at a number of ways of dealing with hydrogen sulfide. Ormat, whose plant is due to begin coming on line later this year, is taking a cue from geothermal development at Coso, Calif., north of the Imperial Valley, where developers have had success with reinjecting hydrogen sulfide and other non-condensable gases — including carbon dioxide — along with geothermal fluids into the underground reservoir.

But hydrogen sulfide is not all there is to worry about.

According to Paul Sweeny, geothermal project manager for the California Regional Water Control Board, geothermal development in the valley poses a major challenge in the management of solid and liquid wastes.

"The voluminous amounts of wastewater and solid wastes that are generated by the industry must be managed to prevent any adverse impacts to ground waters, surface waters, farmland, federal lands and biologically sensitive areas," he said.

A few of the threats to water quality, according to Sweeny: drilling muds and fluids, including chemical drilling additives; injection wells, injection and production well sump ponds used to contain geothermal fluids when reinjection is not possible; cooling tower chemicals; filter residues and drill cuttings; radioactive solids in the waste; and the landfills at which the wastes are stored.

Sweeny estimated the valley's geothermal plants generate 145 tons of solid waste and more than 84 million gallons of liquid waste a day, with most of the latter being reinjected into the underground geothermal reservoir.

Aside from inert drilling muds and cuttings, the solid waste includes tons of filter cake extracted from the highly saline geothermal brines of the Salton Sea area. Though mostly silica, the material includes low concentrations of arsenic, lead, mercury and other potentially toxic substances and thus is treated as hazardous.

Regulators are also concerned about low levels of radioactivity in the filter cake. Although they do not regard the material as a threat to public health and safety, officials have advised state inspectors to limit their exposure to the substance and to wear respirators and protective clothing when in portions of geothermal facilities where bits of the filter cake may be airborne.

Some of the solid waste from the facilities is mixed with other materials to form a "geocrete" used to pave roadways and other surfaces on-site. The rest is disposed of at a state-approved landfill operated by GSX Services Inc. A proposal is pending by a subsidiary of Magma Power Co., which operates four plants in the Salton Sea area, for a dedicated "monofill" to receive wastes from the plant.

The filtration that produces the cakes is made necessary by the high content of dissolved solids in the Salton Sea resource, which at up to 300,000 parts per million of total dissolved solids has five times or more the dissolved solids of Hawaii's geothermal resource.

The hot brines that fuel the valley's geothermal plants also present a waste management problem, according to Sweeny. The brines are higly corrosive, and most plant operators have had to report major spills, some running into the thousands of gallons.

The salt-laden hot water kills whatever it touches, Sweeny said, forcing the plants's operators to occasionally have to reimburse farmers for damaged crops.

"We also make them scoop out all contaminated soil and replace it," he said.

Corrosion and scaling can also cause failures of the well casings that are supposed to protect ground water from contamination by geothermal fluids. Sweeny noted that an injection well at a Chevron facility in Heber, Calif. suffered such a casing failure recently.

Asked if he had any advice for Hawaii officials who will be charged with regulating geothermal development, Sweeny said vigilance is the key.

"You really have to keep a keen eye on these operators on an almost daily basis," he said. "It's very easy for them to say, 'that was only a few hundred gallons (of brine) we spilled,' but when you add it all up, cumulatively, it can be quite an impact."

Tomorrow: How long will Imperial Valley's geothermal resources last?

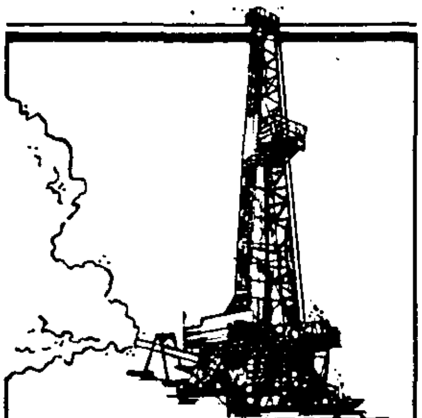
Hawaii Tribune-Herald
May 27, 1990

In Imperial Valley, no flap over geo

Editor's note: Geothermal development is an issue of great contention on the Big Island, with the first geo plant scheduled to come on line later this year despite many protests over what opponents say will be negative impacts on the environment. Supporters, meanwhile, challenge such environmental claims and say the alternative energy technology is relatively benign when compared to other power sources.

Last month, at the invitation of the Pro-Geothermal Alliance, the Tribune-Herald's geothermal reporter, Dave Harada-Stone, travelled to Southern California to see several geothermal plants and how they've fit in with their surrounding communities. Besides touring the plants, Harada-Stone also met with local officials to see how the promises made when geothermal development was first proposed have jibed with the reality. The following is the first in a three-part series.

By Dave Harada-Stone
Tribune-Herald



GEOTHERMAL

The record in Southern California

EAST MESA, Calif. — To the untrained eye, this parched, barren stretch of California appears to be little more than wasteland, the kind of God-forsaken place where you expect to see cattle carcasses on the roadside and buzzards overhead.

But that's to the untrained eye.

To the biologist, East Mesa is a precious and vital desert habitat, home to the threatened flat-tailed horned lizard and other reptiles, as well as such species as coyotes, rabbits and kangaroo mice.

Criss-crossing that habitat is a network of pipelines leading to six geothermal power plants. The plants, all developed within the past decade, generate 131 megawatts of electrical power, or enough to meet the needs of about 130,000 households.

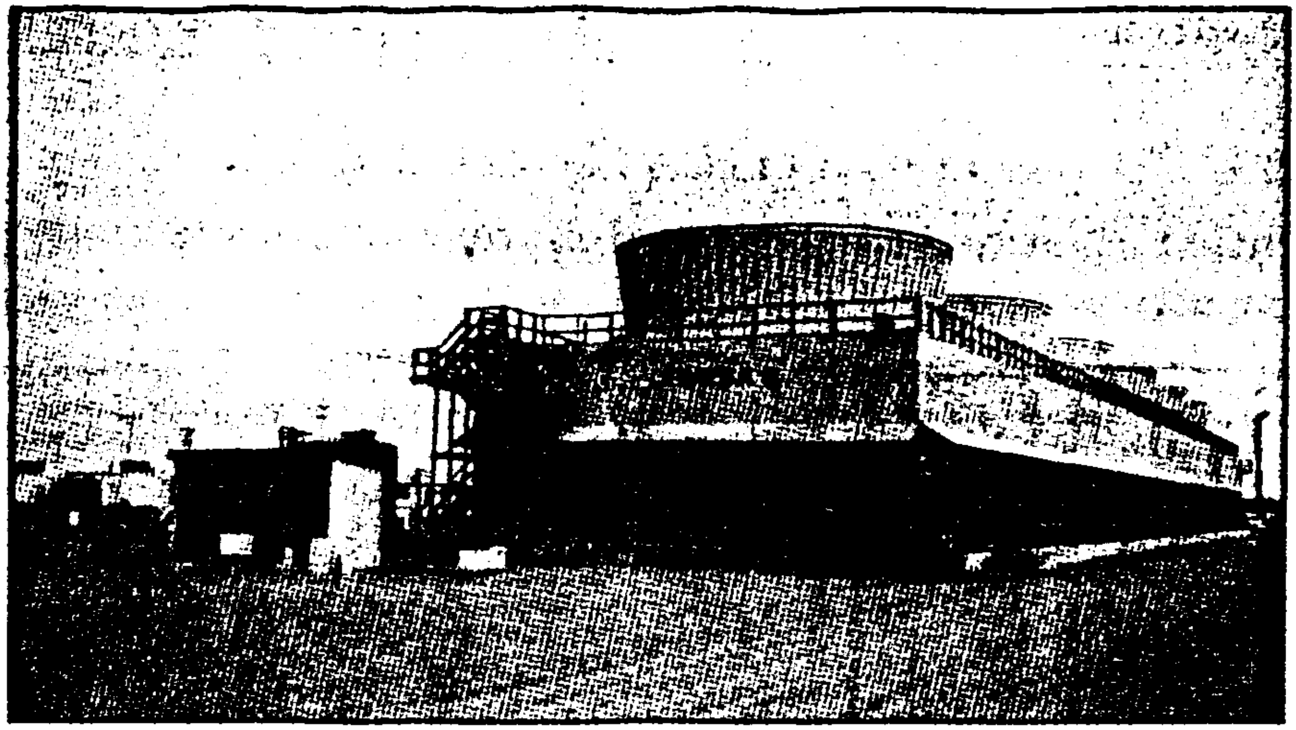
The wells feeding the plants tap into an underground reservoir of brine at depths of 4,000 to 6,000 feet, where the salt-laden water is heated by pockets of magma to temperatures between 290 and 350 degrees Fahrenheit.

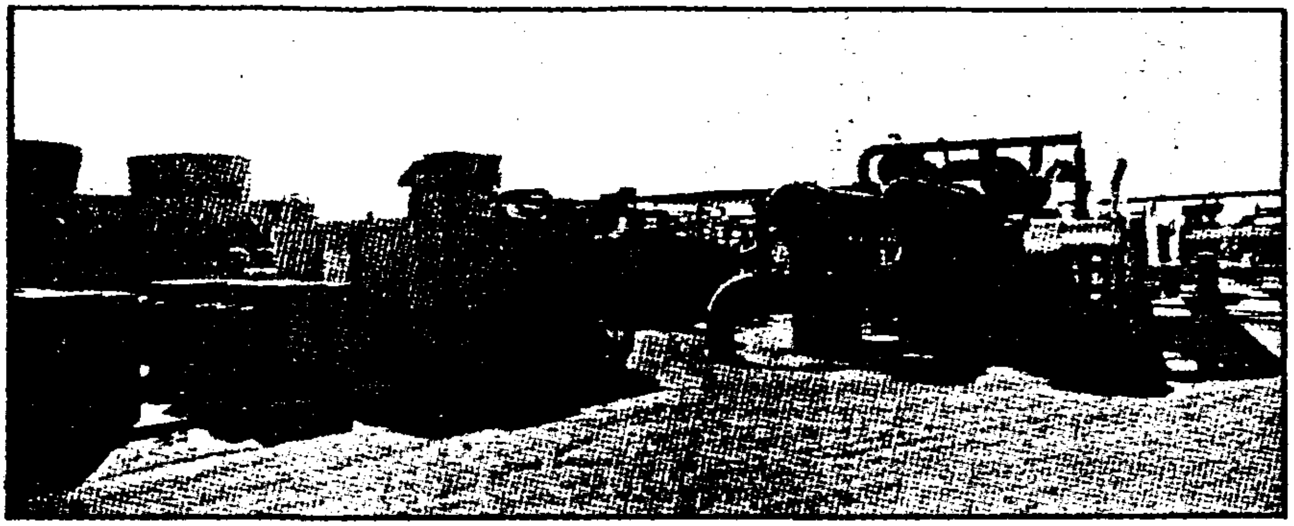
The temperature is relatively low for a geothermal resource, forcing developers to overcome a few thermodynamic hurdles to turn the heat into power.

According to Yona Yahalom, manager for project engineering for the Ormesa geothermal complex developed in the desert by Ormat Energy Systems, the geothermal reservoir beneath the East Mesa was ignored for years by would-be developers eying the Imperial Valley area.

"The resource was considered uneconomical," he explained.

What Ormat did was utilize a





CALIFORNIA STEAMING — Ormat's Ormesa geothermal complex, parts of which are shown above, was built in recent years on environmentally sensitive desert lands in East Mesa under the jurisdiction of the federal Bureau of Land Management. The East Mesa geothermal field is one of three being actively exploited in the Imperial Valley, a vast, arid agricultural area in southeast California bordering Arizona and Mexico.

binary process in which the geothermal resource is used in its liquid state — rather than being flashed to steam as it is in most plants — to heat a working fluid, isopentane, that boils at a relatively low temperature. The vaporized working fluid is then used to turn a turbine attached to a generator.

The process, similar to that to be used in Ormat's planned Puna Geothermal Venture project in Pohoiki on the Big Island, takes place in self-contained units dubbed "Ormat Energy Converters." Prefabricated and assembled in series on the project site, the units are arranged so as to squeeze as much electricity as possible out of the resource, with each batch of converters generating power from lower temperature fluids.

The arrangement allows Ormat to boost its generating efficiency from 12 to 16 percent.

"That doesn't seem like much," Yahalom said, "but those four percentage points actually represent a 25 percent improvement."

Should one of the units fail, the others can continue operating, thus helping Ormat to maintain a reliability factor Yahalom says is more than 99 percent.

Once their thermal energy is spent, the fluids are reinjected into the geothermal reservoir and the isopentane is condensed back into liquid form.

Each of Ormesa's four plants, with a combined output of 54 megawatts, is tied to a control room where technicians monitor

See GEOTHERMAL, Page 3

GEOTHERMAL: In Imperial Valley, plants 'fit in well'

From Page 1

fluid flow rates, temperatures and other variables represented graphically on computer screens.

The two smaller plants, Ormesa IE and IH, can essentially run themselves, Yahalom said. Plans call for the plants to be left unstaffed at night and on weekends, with technicians at Ormesa I monitoring conditions from their site.

The Ormesa plants, and two neighboring facilities operated by Geothermal Resources International, are on leased federal lands under the jurisdiction of the Bureau of Land Management. The lands have a Class L designation, meaning that access is limited in an effort to minimize human impacts on what is largely a wilderness area.

According to John Whitley of the bureau's El Centro Resource Area office, the plants have proven to be desirable tenants.

"There are no emissions, no discharges and no noise," he said. "They've fit in very well."

While the steady hum of the turbines can be heard during a walking tour of the plants, there is little noise evident at the facilities' boundaries.

Whitley noted that the developers elevated the miles of pipeline carrying geothermal brines from the wells to the plants, a measure he said "cost quite a little bit of money," but ensures uninhibited passage for animals in the area.

The East Mesa field is one of three being actively exploited in California's Imperial Valley, an agricultural region bordering Mexico and Arizona. The others are located on the southeast coast of the Salton Sea, about 35 miles to the northwest of here, and Heber, about 15 miles to the southwest.

Altogether, the 200-plus wells tapping the valley's geothermal resource feed 14 power plants with a combined capacity of more than 400 megawatts.

Geothermal power generation in the valley has made the transition from the drawing board to the field quickly, with most of the development taking place in the past 10 years.

In terms of the number of wells drilled, plants built and money spent, California officials say, the Imperial Valley's geothermal resources have been among the most actively exploited anywhere in the world in the past few years.

Although the valley's geothermal output is but a fraction of the 2,000 or so megawatts of installed capacity at the Geysers geothermal field in Northern California, development in the valley accounted for more than half of all the state's geothermal drilling and construction in the past two years.

Therein lie some important similarities to the proposals pending for large-scale geothermal development in Hawaii. As happened in the valley, developers eyeing Puna's resource hope to go from zero to several hundred megawatts in a few years. And as the valley now does, the Big Island would export most of the power, though through a far more complex transmission system than is used in California, where the power is routed through the Imperial Irrigation District for sale to Southern California Edison.

But unlike efforts to tap Hawaii's geothermal resources, the development in the Imperial Valley has proceeded with a minimum of controversy and protest.

"There's been very little," said Tim Boardman, geothermal district engineer for the California Division of Oil and Gas. "Actually none, zilch."

He noted that most of the valley's geothermal plants are in remote areas, bordering broad stretches of farmland, or, in the case of the East Mesa, desert.

They are also spread through a county of 4,173 square miles — or an area a little larger than the entire Big Island — with a population of 92,000 — about 30,000 less than that of the Big Island.

"This is also a very depressed area of California," Boardman said. "The unemployment rate is more than 20 percent. Any means to bring in jobs is welcome."

And, Boardman says, geothermal is relatively clean, at least when compared with coal and oil-fired plants, few of which have been built in California in recent years.

Far from fearing geothermal's impacts, area farmers have a financial stake in the alternate energy technology's success.

"By and large, it's a very symbiotic relationship," said Paul Sweeny, geothermal program manager for the California Regional Water Control Board Board, Region 7.

He noted many of the farmers receive lease payments from the developers for wells drilled on their lands. There have been problems, including spills of hot brine that kills just about anything it touches.

"But they're paid full value for any damaged crops," Sweeny added.

And plant designers have made an effort to get their creations to fit in.

The geothermal plant operated in Heber, Calif. by a subsidiary of ERC Environmental and Energy Services Co. — another subsidiary of which is currently working on a master plan for geothermal development in Hawaii — is one example of that.

Surrounded on all sides by farmland, the 47-megawatt complex was engineered to occupy a minimum of space. The plant and adjacent well field cover less than 40 acres.

All of the production wells, operated by Chevron Geothermal Co. and Unocal Corp.'s Geothermal Division, originate from a central five-acre production island. The wells are drilled at various angles into the center of the geothermal reservoir, where brines at temperatures exceeding 360 F are tapped to fuel the plant.

Started up in 1985, the ERCE plant was the first commercial geothermal facility in Imperial County to receive the necessary permits from county planning officials. The East Mesa plants are subject to federal regulation.

"The farmers love it," said plant general manager Robert Sones of the community's reaction to the facility. "We haven't had any complaints."

The plant produces no odors, and while its equipment generates some noise, it is not noticeable at the project boundary.

Unlike Hawaii's resource, the geothermal fluids beneath the valley are naturally low in hydrogen sulfide, a noxious gas with a rotten-egg-like odor. Recurring hydrogen sulfide releases from Hawaii's experimental HGP-A power plant in Pohoiki made life miserable for many nearby residents, befouling their air and sending some people to the hospital complaining of eye and lung irritations and other symptoms.

Even on a windless day, one cannot smell the gas at the fence lines of most of the Imperial Valley's plants. Its telltale odor is barely perceptible even atop the plants' cooling towers, through which hydrogen sulfide and other non-condensable gases are emitted.

But developers and regulators must still contend with such things as brine spills, sump ponds and solid wastes, the latter including silica taken from the extremely saline brines of the Salton Sea area and laced with trace amounts of toxic chemicals and heavy metals.

The Salton Sea Geothermal Field, located near the southeast shore of California's largest lake, is the most productive field in the Imperial Valley area, boasting six power plants with a combined net output of 193.8 megawatts.

As in the case of East Mesa, the developers of the Salton Sea field had to overcome a few technical obstacles to make development viable.

While the Salton resource is hotter, with an average temperature of 500 F, it is of a much poorer quality, with total disolved solids in the brine ranging from 200,000 to 300,000 parts per million — or up to 30 percent by volume.

Unchecked, the solids, which are mostly silica, can muck up a power plant's works, clogging pipelines and plugging up the cracks in the earth into which the spent fluids are reinjected.

At the "dual flash" Salton Sea Unit 3 power plant operated by Unocal Corp., brine flows from a wellhead separator into a pressure crystallizer in which steam "flashes" from the hot fluid. The steam leaves through the top of the crystallizer vessel and is routed to a turbine to generate electricity. The brine flows into a low-pressure crystallizer, where a further drop in pressure produces more steam, which flows to the turbine through a separate pipeline.

The brine, reduced to atmospheric pressure, flows by gravity into a clarifier and thickener and then a secondary thickener. Both chambers remove solids that have precipitated from the brine, leaving the remaining fluid clean enough to be reinjected into the underground reservoir without plugging the injection wells.

Some of the solids are recycled to the crystallizers as "seed" material, attracting other solids and thus reducing scaling in the vessels and pipes.

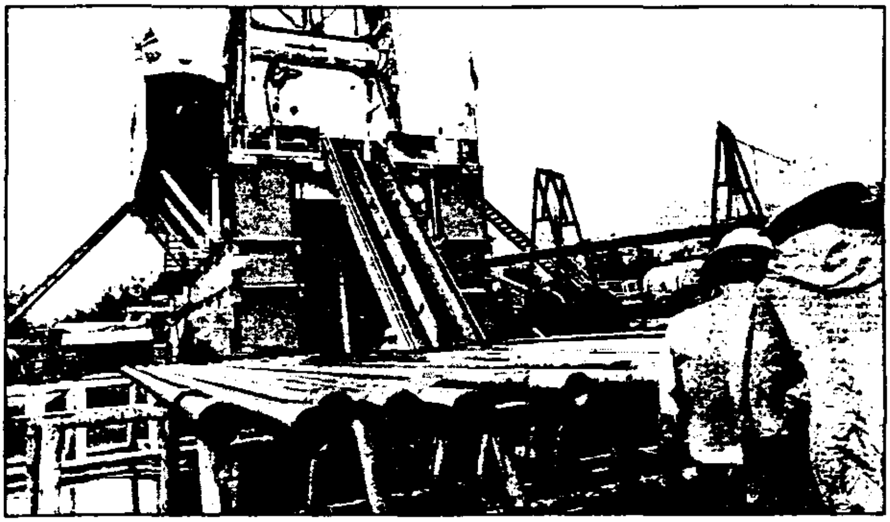
Excess solids are extracted in the form of a filter cake, which in Unocal's case is mixed with other ingredients to form a building material dubbed "geocrete." The material is analyzed for toxic compounds and permeability before being used to pave roads and other surfaces around the plant.

Unocal's Salton Sea plant also boasts the world's largest geothermal well. Vonderahe 1 churns out 2.5 million pounds of geothermal fluid an hour. By way of comparison, engineers expect each of the geothermal wells planned for Ormat's Puna geothermal project to produce 69,000 to 112,000 pounds of steam and fluid an hour.

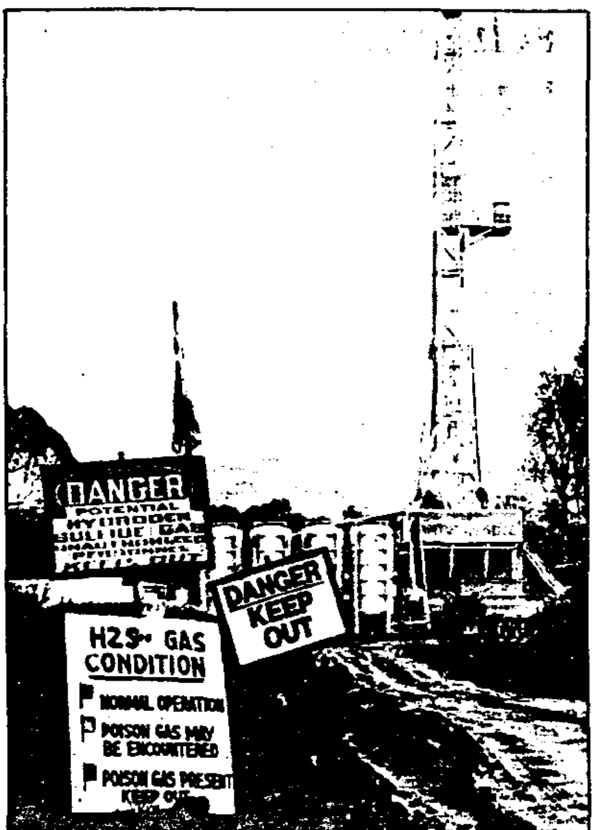
Tuesday: Protecting the earth from what lies beneath it.

Geothermal: Big protests sparked by issue

SUNDAY ADV. 5/13/90



Pipes marking the location of the True/MidPacific drilling site lie in the Puna rainforest.



Advertiser photos by Bruce Asato

Signs warn of hydrogen sulfide gas emissions at the True Geothermal drilling site in Puna.

KILAUEA RIFT:
The Geothermal Power Struggle

Today:
Boon or bane?
Draft plan delayed
Kalakaua meets Edison

Tomorrow In The Advertiser:
To tap a deep caldron
120,000 leagues under the sea
Losing steam at the Geysers

Tuesday In The Advertiser:
Fumes of burning stone
Lake County's growing pains

Wednesday In The Advertiser:
In the ahupua'a
High tech in the high desert
Invasion of the mud volcanoes

Geothermal furor:

5-13-90

Long-simmering controversy now reaching a boiling point in Hawaii

By Jim Borg
Advertiser Science Writer

PAHOA, Hawaii — A yellow flag at the entrance to the eight-acre clearing warns of possible poisonous hydrogen sulfide gas in the air.

If there is any, the telltale rotten-egg aroma is lost in the rain pounding on the gravel road and surrounding forest of ohia and strawberry guava.

At the far end of the clearing stands a 176-foot-tall metal drilling tower.

Invisible just a half mile away, but imposing this close up, the rig represents one of the most divisive issues in Hawaii's history:

Geothermal energy.

Advocates say it's the best way to reduce Hawaii's overwhelming dependence on oil to generate electricity. Tapping pockets of hot water and steam under Kilauea's East Rift Zone is technically feasible and relatively benign on the environment, supporters insist.

Opponents say large-scale geothermal power at Kilauea is unproven, unsafe and unnecessary, if modern energy conservation approaches are followed. Further, they say, spinning a steel-and-concrete web of steam wells, power plants, pipelines, roads and electrical transmission lines along the volcano's central eastern flank will chew up precious acres of native forest.

Not since the Vietnam War have protesters turned out in such numbers to be hauled off in handcuffs. The issue pits scientist against scientist, and has generated discord within the Democratic Party and Gov. John Waihee's Cabinet.

"The Republicans have abortion and we have geothermal," Waihee told reporters Tuesday, referring to the Hawaii County Democratic Convention last weekend in Hilo.

After lengthy debate, the Big Island Democrats agreed to support development of 50 megawatts of geothermal power for the local utility —

See Geothermal, Page A8

KILAUEA RIFT: The Geothermal Power Struggle

FROM PAGE ONE

but not at the expense of any further rainforest clearing.

Here, in the heart of the Wao Kele O Puna forest, the latest search is on for magma-heated water and steam.

A partnership of two Wyoming companies, True Geothermal Energy Co. and Mid-Pacific Geothermal Inc., hopes to develop an initial 25 megawatts of power — about a fifth of the Big Island's needs — in the 9,014-acre Kilauea Middle East Rift Geothermal Resource Subzone.

True attorney and project coordinator Allan Kawada says the drill hit some kind of geothermal resource in early April, but he won't say exactly what. The well's production potential remains a business secret, says Kawada.

"You've got the heat, no question, and you've got the water," Kawada says, waiting out the downpour in a small open-sided shelter. "But whether you've got the cracking and fragmenting and permeability so that you get a good mix is the question. We're going to drill a lot of holes (up to 12) before we commit."

For the time being, the well has been shut down as the company analyzes its data on the resource, says Kawada.

Under an order by Circuit Judge Shunichi Kimura, True/Mid-Pacific was prevented from clearing forest to drill at any other sites. But Kimura lifted the ban in a decision last Wednesday relating to a lawsuit by the anti-geothermal Pele Defense Fund.

Geothermal: A quick look

Here's a quick look at geothermal development, past, present and future, on the Big Island:

- **Name:** Hawaii Geothermal Project-Abbott (HGP-A)
  Capacity: 2-3 megawatts
  Status: Closed, Dec. 1989
- **Name:** Ormat Energy Systems (Puna Geothermal Venture)
  Capacity: 25 megawatts
  Status: Awaiting permits.
- **Name:** True/Mid-Pacific
  Capacity: 25-100 megawatts
  Status: Drilling first well
- **Name:** Hawaiian Electric Co.
  Capacity: 500 megawatts
  Status: Reviewing two bid proposals

While geothermal power clearly carries safety and environmental concerns, a new dimension has unfolded with the rainforest debate. The argument finds avowed environmentalists in the odd position of opposing an alternative to fossil fuels.

The Pele Defense Fund, for instance, became an official intervenor at the Public Utilities Commission in favor of Hawaii's first major coal-fired power plant, a $383-million project of Applied Energy Services (AES-Barbers Point Inc.) With a ground-breaking ceremony held last Thursday at Campbell Industrial Park, the plant is expected to provide 180 megawatts of capacity to Hawaiian Electric by September 1992.

For a while, The Rainforest Action Network in San Francisco mistakenly characterized Hawaii's geothermal development as threatening "the last lowland tropical rainforest in the United States." They have since changed the description to "last *large-expanse* lowland tropical rainforest," a term with which geothermal proponents don't quibble.

Beneath the often messy exchange of charges and countercharges, a close examination of geothermal issues reveals these facts:

- The best-preserved tracts of Puna's rain forest — that is, pristine ohia land still without interloping foreign species — lie in areas removed from from where the state permits geothermal development.
- Technology is available that would prevent irritating emissions of sulfur dioxide. These are being used by both Pacific Gas & Electric Co. and California Energy Co., members of competing groups now in negotiations with Hawaiian Electric for the second-stage proposed 500-megawatt geothermal/cable project.
- The problem of noise from

drilling operations near residential communities will have to be addressed. Mufflers, lead shields and other techniques have been used with some success at The Geysers geothermal field in Northern California. There is no [illegible] noise [illegible] geothermal pow-

● Turbines, with a capacity of 25 to 30 megawatts, are from small to large plants at [illegible] because they can be put on line quickly. Large plants, like the 135-megawatt facility at The Geysers, require huge amounts of steam or hot water that might not be readily available at Kilauea, and represent a crushing loss if destroyed by lava.

In the thick of the geothermal power battle is the Campbell Estate, which in 1985 traded its 25,807 acres at Kahauale'a, adjacent to Hawaii Volcanoes National Park, for the state's 27,785-acre Wao Kele parcel.

"It became clear in the findings and discussions relating to the initial site that (the parcel transferred to the state) was the far more pristine area," says Clint Churchill, the estate's chief executive officer and chairman of the Pro-Geothermal Alliance. "The native forest was of much higher quality than the Wao Kele O Puna forest, so it made better sense to preserve that area and transfer the Natural Area Reserve to the better forest."

The swap, under challenge by the Pele Defense Fund, was upheld May 4 by the 9th U.S. Circuit Court of Appeals in San Francisco. Pele Defense Fund attorney Yuklin Aluli says the issue now will be pursued in state courts rather than the U.S. Supreme Court.

As a condition of the exchange, the state would get 10 percent of the gross revenues earned through geothermal activities at Wao Kele, and one-fifth of that 10 percent should go to the state Office of Hawaiian Affairs.

But Aluli argues that native Hawaiians who hunt pigs and gather medicinal herbs in Wao Kele have already seen their traditions and livelihoods irreparably harmed by the drilling operation.

A major factor in the battle for public opinion remains the spotty record of the state's HGP-A demonstration plant. The 3-megawatt generator closed down last December after alienating its neighbors in Leilani Estates with periodic noise and sulfur stink.

On 500 acres adjacent to the HGP-A site in Kapoho, Ormat Energy Systems of Nevada, operating as Puna Geothermal Venture, has permission to install wells and generators to produce another 25 megawatts. The 1990 Legislature approved spending $250,000 to reopen the HGP-A well and sell the hot water to Ormat.

While [illegible] available [illegible] problems, many [illegible] ply have lost faith in [illegible] tem, says state Sen. [illegible] Levin, D-1st District (Kailua-Kona-Ka'u-Puna).

"For a decade, people living in the shadow or downwind of HGP-A have complained about the noise, pollution and health effects of geothermal," Levin said in an interview. "They were lied to or ignored by the government. We were told through the '80s, HGP-A is clean, efficient, state-of-the-art. Now we're told it was just an experimental project that should have been shut down long ago."

Ormat is ready to begin drilling as soon as it gets county approval of its plans for air and water quality, noise monitoring and emergency response, said Maurice Richard, regional development manager.

Once those tickets are punched, "we should begin drilling within 30 days," said Richard. The company [illegible] committed itself to a rapid [illegible] duction schedule, guarante[illegible] Hawaii Electric Light Co. [illegible] 10 megawatts by the e[illegible] the year, and the bala[illegible] the 25 megawatts in fir[illegible] ter 1991, he said.

Since its site is on a[illegible] al land, Ormat has [illegible] to stay on the good [illegible] Rainforest Action [illegible] San Francisco.

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Tomorrow[illegible] er: Subterr[illegible]

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Tapping into a subterranean furnace

Elsewhere in the world, pace of geothermal development accelerates

Second of four parts

By Jim Borg 5/14/90
Advertiser Science Writer

Don Thomas enjoys getting into hot water.

A research geochemist with the University of Hawaii, Thomas has studied the lava-rock bowels and subterranean caldrons of Kilauea Volcano since 1972.

Testifying in an unofficial capacity before the Legislature last month, he was clearly annoyed.

At issue was a resolution calling for a deceleration in the state's plans for development of geothermal wells and power plants on the Big Island.

"It is difficult for me to conceive how geothermal development in Hawaii could be much slower without a complete halt and abandonment of the program," Thomas said.

"In the nearly 15 years since the geothermal resource was discovered on the Kilauea East Rift Zone, we have managed to develop one 3-megawatt demonstration power plant," he said. "During this same period, California has added approximately 800 megawatts in The Geysers field and more than 100 megawatts in the Salton Sea . . .

"The Philippines have developed more than 800 megawatts in fields that were identified after that on the East Rift Zone in an even shorter time period."

Thomas was right that geothermal development has been slow here, but in most areas the pace is picking up.

Hawaiian Electric Co., facing a December deadline, is negotiating in private with two competing groups of companies that have offered proposals for a state-backed 500-megawatt geothermal project. The power would be carried from the Puna District to Honolulu by an undersea transmission cable, the deepest in the world, beginning in 1995.

Former Gov. William Quinn, chairman of Gov. John Waihee's geothermal advisory board, has called it "far and away the largest project ever contemplated in the state of Hawaii."

Meanwhile, after long delays from legal challenges and contested permits, two smaller geothermal enterprises are figuratively, if not literally, gathering steam.

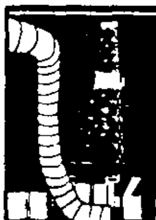
One partnership, True/Mid-Pacific, has completed its first well in the Puna rain forest, while the second company, Ormat Energy Systems, known as Puna Geothermal Venture, although still without a well, has promised to deliver 7 to 10 megawatts to Hawaii Electric Light Co. by year's end.

Opponents of geothermal power here have been eager to point out that steam production at The Geysers in northern California has declined unexpectedly over the last three years.

But scientists agree the geology of the two fields is completely different.

While The Geysers is a tightly enclosed subterranean sandstone reservoir containing almost pure steam,

See Geothermal, Page A4



KILAUEA RIFT:
The Geothermal Power Struggle

Today: To tap a deep caldron
On Page A3:
120,000 leagues under the sea
Losing steam at the Geysers

Tomorrow in The Advertiser:
Fumes of burning stone
Lake County's growing pains

Wednesday in The Advertiser:
In the ahupua'a
High tech in the high desert
Invasion of the mud volcanoes

5/14/90

Geothermal: Development pace is issue

FROM PAGE ONE

Kilauea, they say, is built on permeable lava-rock formations through which hot water circulates quickly and is replenished easily by rain.

"Virtually every water-dominated geothermal system has recharge," says Thomas. "It has to."

This rapid circulation has led some critics to suggest that seawater or rainwater would effectively dissipate the heat. Anti-geothermal groups also point to a drop in production at the state's defunct HGP-A geothermal plant, from 3 megawatts to 2.4 megawatts over its lifetime.

"The claim that seawater will lead to quenching of geothermal wells is speculation that is unsupported by eight years of production of fluids from the HGP-A well, during which time the temperature of the fluids remained virtually constant and the chemistry indicated no appreciable cooling in the vicinity of the well bore," Thomas responded.

"Individual wells may have a finite lifetime — 10 years, 20 years or longer, depending on the nature of the resource," he said. "To declare the resource as being non-renewable because wells have to be replaced is the same as saying that solar is non-renewable because solar cells have to be replaced periodically."

Based on scientific test drilling, Thomas estimates that Kilauea's geothermal zone holds the equivalent of 1,400 megawatts of electricity.

By geothermal or "earth heat" energy, scientists mean the underground soup of water and minerals that magma creates in two basic forms:

- dry steam — that is, nearly all steam with no water.
- superheated water, which may have a temperature of nearly 700 degrees Fahrenheit — well above its normal boiling point of 212 degrees — because of the immense gravitational pressure exerted by the rock and water above.

Although the flanks of Kilauea are believed to house some dry steam, the prime resource is believed to be brackish water that lies about a mile below sea level. Tapping these reservoirs can produce energy in a variety of ways.

Dry steam is pumped more or less directly into a generating turbine, which is tailored to the specific pressures and temperatures of the resource.

In a so-called "flash steam" power plant, hot water is brought to the surface by pipes and fed into a container called a separator, where steam rises from the water or brine. The brine is pumped back into the ground through an injector well. (The troublesome HGP-A plant put the brine into holding ponds.)

Don Thomas
Says Hawaii is snoozing

The steam goes to the generating turbine, then is condensed and also reinjected. The cooling tower emits air and water vapor.

So-called non-condensable gases — hydrogen sulfide, chiefly — are either scrubbed out during the cooling process or, in the case of California's Coso Geothermal Project, reinjected into the ground.

In a "double flash" plant, steam is separated from the brine a second time at a lower pressure.

In a binary cycle plant, a less efficient and more expensive system, the hot water passes though a heat exchanger, then back into the ground. The heat is picked up by another fluid, commonly isobutane, which turns a turbine as part of a closed cycle.

Unlike HGP-A, modern geothermal plants have turbine-bypass systems that run the steam through the normal abatement systems when the turbine, for one reason or another, must be shut down.

What about the integrity of the well pipes? Could they crack open during earthquakes, spewing brackish, chemical-laden geothermal brine into fresh ground water?

Could the reinjection process cause its own ruptures?

HGP-A's steel well pipes, separated from the surrounding earth by concrete, sustained earthquakes of 6.1 and 6.6 magnitude without cracking, Thomas says. Those natural quakes are far larger than any disturbances generated by reinjection, he adds.

Second, breaks in well pipes can be detected and repaired.

Third, the ground water along Kilauea's East Rift Zone is naturally salty and warm.

"You have to recognize that groundwater in that area is not considered to be potable," Thomas said in an interview. "It has natural geothermal discharge in it."

The Hawaii Legislature this month approved $3 million for research drilling and assessment of the Puna area's geothermal resources to determine if and where 500 megawatts of geothermal energy exists.

The research, conducted through a series of UH "scientific observation holes," received $2.6 million this fiscal year.

Along with the size, extent, temperature and composition of Kilauea's geothermal fluids, the question of cost remains troublesome.

Estimates have ranged from $1.7 billion from HECO and the state to $4 billion from Mainland consultants hired by anti-geothermal camps. Thomas says the costs will "remain speculative" until many more wells have been drilled.

But some critics have already heard enough.

"In all my years of experience, I have never seen the development of a major generation plant treated in such a cavalier and unplanned manner as this geothermal project," says Maui resident James Williamson, a former Seattle civil engineer, now retired, who is familiar with geothermal plants in California and Iceland. "When I first became aware of this 500-megawatt geothermal installation in the most active volcano in the world — and an unprecedented high-voltage submarine cable to Oahu, I did not believe it to be a serious proposal.

"Inherently it has to be more expensive than conventional oil- or coal-fired generation," says Williamson. "And there is no question that its environmental impacts will be far greater."

Tomorrow In The Advertiser: The Sound and the Sulfur

KILAUEA RIFT: The Geothermal Power Struggle

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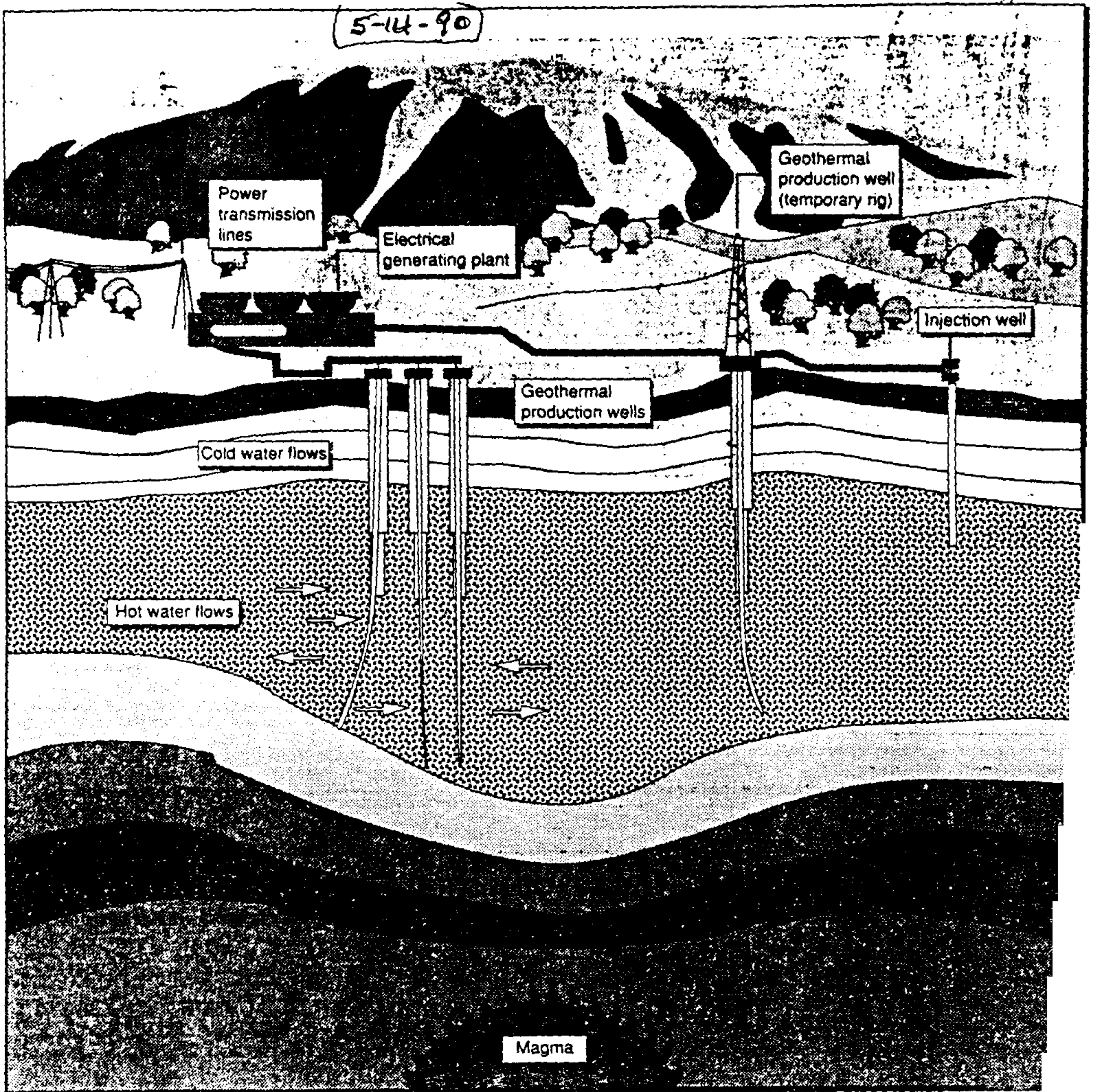
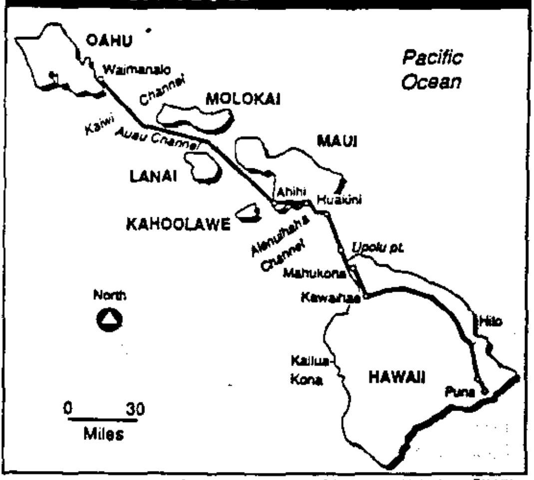


Advertiser graphic by Greg Taylor and Rick

The cable route



Advertiser graphic by James Takamiya

5-14-90

Hurdles for cable: environmentalists, and Mother Nature

The "preferred" route keeps changing.

It used to go through the Saddle between Mauna Loa and Mauna Kea, but the Army complained the overhead transmission wires might snag helicopters using Pohakuloa Training Area. So now the route passes north of Mauna Kea on its way to North Kohala, where it enters the sea.

From there, to its ultimate landfall in Waimanalo, the Hawaii Deep Water Cable would traverse 138 miles and the 6,300-foot-deep Alenuihaha Channel between the Big Island and Maui, making it the world's longest and deepest electrical transmission cable.

The scheme has drawn angry opposition from some environmental groups, including the Sierra Club and Hawaii Audubon Society, which cite potential damage to reefs and landing areas, including Maui's Ahihi-Kinau Natural Area Reserve.

A cable carrying power 120,000 leagues under the sea also would be vulnerable to submarine earthquakes and landslides, forcing Hawaiian Electric Co. to install an equal amount of oil-fired generation as backup, critics claim.

Not so, says HECO spokesman Scott Shirai.

At least two cables will make the interisland crossing, and a third may span Alenuihaha. HECO's request for proposals specified that the loss of one cable would not exceed the largest generating unit on Oahu, 146 megawatts.

That means that HECO would already have enough "spinning reserve" on Oahu to make for the loss of a cable, said Shirai.

From 1981 to 1988, with support from U.S. Sens. Daniel Inouye and Spark Matsunaga and Rep. Daniel Akaka, Congress approved $23 million for cable research through the U.S. Energy Department. Another $5 million came from the state.

The cable's designs and test lengths are the work of the Pirelli Cable Corp., an Italian company with U.S. headquarters in Union, N.J.

If large-scale geothermal gets the go-ahead, Pirelli stands to receive a contract worth at least $400 million to complete at least 276 miles of cable.

Since it became the project's lead cable company in August 1983, Pirelli has made its interests known on Capitol Hill through a lobbying firm and thousands of dollars in campaign contributions and honoraria to key committee members, according to The Washington Post.

Still undecided is the timetable for installing the cables. If deemed feasible, the power plants would be phased in over 12 years beginning in 1995.

What about the danger from eruptions from Kilauea Volcano?

"They have to take their chances," says Richard Moore, a geologist with the U.S. Geological Survey on the Big Island from 1977 to 1987. "No eruption may occur in one spot for hundreds of years, but ... it might get buried the next year."

Moore, now based in Denver, said geologists are waiting to see what happens after the current seven-year eruption ends. "Will activity migrate uprift from there or downrift?" he asks.

— Jim Borg

California steaming: Geysers show geothermal potential

By Jim Borg 5/14/90
Advertiser Science Writer

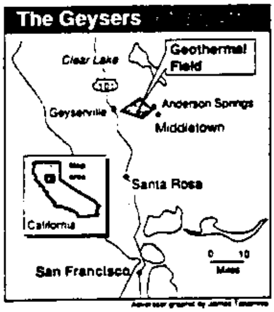
GEYSERVILLE, Calif. — Along Sonoma County's Big Sulfur Creek, wisps of steam against the green hillside offer the first hint of human activity.

A closer look reveals the characteristic cooling towers and a network of pipes that resemble the legs of a huge spider.

Farther down the winding road, more pipes and plants emerge from the mountainous terrain.

Straddling the border of Sonoma and Lake counties in northern California, the one-time resort area known as The Geysers encompasses the world's largest and most successful geothermal energy field.

Nestled above California wine country, the rock-encased reservoir of 355-degree steam feeds plants engineered to pump out 1,900 megawatts of electricity. That's a little shy of generating capacity in the entire state of Hawaii.



But after a decade of heavy development, the reservoir is literally running out of steam, with power production dropping dramatically and future plant construction curtailed.

"Geothermal is not a renewable resource," remarks Harry Bain, a spokesman for the principal steam developer at the Geysers, Union Oil Co. of California. "We recognized that it would deplete. I think that what caught everyone by surprise is the depletion accelerated ... At first, nobody wanted to believe it."

Environmental and production problems at The Geysers have been used as ammunition against proposed large-scale geothermal power in Hawaii.

But while the energy potential of The Geysers was obviously overestimated, geologists say there are important differences between these underground steam pockets and the magma-heated groundwater on the east rift of Kilauea Volcano.

Still, if the steam merchants had it all to do over again, "I think it would be a little slower development that we've had here," says Myron Burr, a resource engineer with Unocal's Geothermal Division in Santa Rosa. "Assess the resource and see how it's going to behave under development."

At this end of the Mayacmas Mountains, underground steam forms from water heated by molten rock or magma, itself the product of immense pressure from a complicated collision of geological faults. A system of fissures allows some steam to escape to the surface.

When bear hunter William Elliott stumbled across the yellow vents in 1847, the overwhelming smell of sulfur — or brimstone — led him to call Geyser Canyon "the gate of Hades."

In the late 19th and early 20th century, The Geysers were a popular resort offering mineral baths and invigorating treks to colorful spots with names like Witches' Caldron and Devil's Tea Kettle. The steam-spewing fumaroles attracted such visitors as Ulysses Grant, Mark Twain and Teddy Roosevelt.

The energy potential was first tapped in 1920, but commercial development didn't arrive for another four decades.

Between 1960 and March 1979, 12 power plants were installed on the Sonoma County side, providing a total of 608 megawatts to Pacific Gas & Electric Co. The two largest plants carried a generating capacity of 106 megawatts.

Against the oil crisis of 1973 and with long delays in nuclear power plant construction, natural steam seemed an ideal energy resource. By the 1980s, large plants were the rule rather than the exception.

"Everybody wanted geothermal," says Burr.

Unocal, Thermal Power Co., and Phillips Petroleum added another six plants with a total capacity of nearly 700 megawatts, including two in Lake County. One of the Lake County plants, designated PG&E-13, with a capacity of 135 megawatts, is the largest geothermal plant in the world.

A number of other smaller private and municipal power generating interests also eagerly tapped into the reservoir, raising the total installed capacity to about 1,900 megawatts. (Hawaii's installed capacity is about 1,950 megawatts.)

Advertiser photo by Jim Borg

Billows of water vapor rise from the ridge-top cooling towers of two 53-megawatt geothermal plants operated by Pacific Gas & Electric Co. in Sonoma County, Calif.

To the consternation of all involved, steam pressure at The Geysers began to fall off rapidly in 1987. As a result, plans for two 140-megawatt plants and a smaller Phillips plant have been scrapped.

And Unocal's 16 PG&E units, carrying a capacity of 1,100 megawatts, have seen a steady decrease in power production to a current average of about 755 megawatts, says Bain.

"Too many straws in the soda," remarks Lake County supervisor Voris Brumfield, a resident of nearby Anderson Springs.

What geologists discovered too late about the Geysers is that the underground steam is surrounded to a large extent by tight formations of rock that prevent the reservoir from being replenished rapidly by rain.

"The hypothesis is that there is natural recharge," says Bain. "We feel it takes place at the edges of the reservoir, but it tends to be a sealed system. As an industry at The Geysers, we're withdrawing those fluids a lot faster than nature can replace them."

One former engineer now with a competing company put it more bleakly. The Geysers, he said, are "not in hydrological communication with the rest of the world."

Engineers have attempted to produce more steam by injecting water into the ground, but the sudden rush of cooler fluid has caused rocks to explode, damaging the well equipment.

Only recently have experiments with re-injection proved encouraging, says Bain.

"We're beginning to see some really dramatic results in a pressure sink where we're injecting," he says. "There are not that many wells involved. We wanted to isolate a part of the field where we can experiment, but in some of these areas we're experiencing almost 100-percent recovery."

Overall, while the steam supply is tailing off, "we're seeing a long tail," says Bain. Unocal expects to provide at least 600 megawatts worth of steam to PG&E through the 1990s.

KILAUEA RIFT: The Geothermal Power Struggle

Deadly gas raises serious questions for Hawaii

By Jim Borg
Advertiser Science Writer

Third in a series

PAHOA, Hawaii — A vapor cloud rose in early April from the True Mid-Pacific geothermal drilling site here on Kilauea's Middle East Rift Zone.

Contrary to the assumptions of many local residents, the steam was not from an underground pocket of volcanically heated water.

Rather, it came from a watery concoction poured down the well hole to cool the drill bit, says Allan Kawada, attorney and project manager for the partnership.

Once in contact with the hot rock and bit, the water boiled — a common occurence in drilling operations, he says.

During drilling, steam is diverted from the drilling rig through what's colorfully called a "blooie line." Sodium hydroxide is added in the line to neutralize the most troublesome geothermal by-product, hydrogen sulfide.

"That enables them to effectively control the hydrogen sulfide during the drilling process," says Bruce Anderson, state deputy director of health.

Sulfur in general and hydrogen sulfide in particular deservedly have a bad reputation.

A word derived from the Latin for "burning stone," sulfur or brimstone has a biblical association with the fires of hell. It occurs naturally in molten rock created from volcanoes or the collision of drifting continents.

Its most common form is as sulfur dioxide.

At the lower temperatures found in geothermal wells, from 300 to 500 degrees Fahrenheit, hydrogen sulfide becomes the more stable chemical species. In large doses, it can kill as efficiently as cyanide.

In April 1983, two geothermal workers lost consciousness and two others were hospitalized when they encountered a pool of hydrogen sulfide at the Kapoho State 1 well in Puna. Because hydrogen sulfide is heavier than air, it may accumulate to toxic levels in low-lying areas.

The drilling company, Water Resources International Inc., later was cited by the state Labor Department for safety infractions relating to the incident. The workers recovered.

Critics of geothermal energy worry aloud about similar but more serious accidents as well as long-term, low-level exposure.

"I have spent several months researching the world's literature on the environmental and health effects of geothermal energy production, and I have come to the conclusion that the unique conditions in Hawaii may preclude its safe development and production here," says Dr. Steven Moser of Maui, who joined the Pele Defense Fund in a lawsuit last year against the Health Department and True Geothermal Energy Co.

Sodium hydroxide, the chemical used to neutralize or "scrub" the hydrogen sulfide in the drilling process, is also toxic, Moser said.

"For every ton of hydrogen sulfide produced during drilling, venting and flow testing, there are four or more tons of sodium hydroxide which must be used," he said. "For each well, tons of this toxic chemical must be disposed of in an environmentally sound way."

Dr. Emmett Aluli, a Molokai physician and an officer with the Pele Defense Fund, has voiced concern that sulfuric acid from geothermal operations could create "acid rain" that will harm forests and wildlife and threaten human health.

Geochemists counter that naturally occuring amounts of sulfur — and sulfuric acid — far exceed those generated by geothermal activity.

Measurements by the U.S. Geological Survey at Puu O'o, where magma from Kilauea releases its gases, show that the volcano emits 1,700 tons of sulfur dioxide a day.

Researchers say the volcano emits hydrogen sulfide, the other gas, at about one-hundredth to one-tenth that rate, which adds up to 17 to 170 tons per day.

The level of hydrogen sulfide emissions from a geothermal power plant depend on just what control technology is used.

But University of Hawaii geochemist Don Thomas estimates a 100-megawatt plant will produce about 0.13 ton per day.

During drilling and well-head flow testing, True Mid-Pacific is limited by the state Health Department to 8.5 pounds per hour (about 0.1 ton per day.)

The limit for Ormat is even tighter — 5 pounds per hour. The tighter standard was set because Ormat is closer to homes and in an area where the geothermal resource is better understood, because of the HGP-A experience.

Says Thomas, "The amount that is coming out of Puu O'o is hundreds of times greater."

Once it mixes with the surrounding or "ambient" air, hydrogen sulfide is conveniently measured in parts per billion.

In its proposed administrative rules for geothermal development, the Health Department has specified an ambient-air limit of 25 parts per billion.

That limit is intended as a "nuisance standard," since it's about the level at which the odor is likely to be annoying, says Anderson. It's also consistent with California's standard.

Using the state-mandated "best available control technology," geothermal developers say, levels of hydrogen sulfide can easily be kept below 25 parts per billion.

The Health Department's permit for Ormat requires that combined emissions do not exceed 5 parts per billion above background levels during normal power-plant operations.

The department's Sept. 20 permit for True Mid-Pacific, issued before the proposed rules, calls for no more than 100 parts per billion for hydrogen sulfide at the property line, but that's likely to be changed once the resource is better understood, Anderson says.

The only time this level may be approached would be during "open venting," says Anderson. During open venting, a process necessary to clean debris out of the well bore, geothermal steam is released directly into the atmosphere.

The Health Department's permit for True Mid-Pacific allows open-venting of wells during the daytime for no more than four hours per day and no more than eight hours total during any well's lifetime.

True's first well has not had to be vented.

Another phase of the drilling process, flow testing, involves venting scrubbed steam and this typically has the most prolonged effect on ambient air quality, Anderson says.

During the problems at HGP-A last Labor Day weekend, measurements of hydro-

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gen sulfide found short-term spikes reaching as high as 46 parts per billion, according to Anderson.

Studies of the health impact of prolonged exposure to low levels of hydrogen sulfide are inconclusive.

For geothermal power plants, about a half dozen hydrogen-sulfide abatement systems are currently available.

At The Geysers in California, hydrogen sulfide and other so-called non-condensable gases are removed by what is known as a Stretford scrubber in the cooling tower complex. Pacific Gas & Electric Co., the principal plant operator at The Geysers, is part of a consortium negotiating with Hawaiian Electric over the proposed 500-megawatt geothermal cable project.

At the Coso Geothermal Project in California's Mojave Desert, hydrogen sulfide is successfully reinjected into the ground under pressure through a sealed well bore. The 240-megawatt Coso project, the first to reinject non-condensable gases, was developed by California Energy Co., part of the other consortium in the running for the mammoth Hawaii project.

Maurice Richard, regional development manager for Ormat/Puna Geothermal Venture, says his firm will try reinjection of hydrogen sulfide at its 25-megawatt plant in Kapoho.

Rod Moss, vice president of Mid-Pacific Geothermal Inc., part of the True Mid-Pacific partnership, says a decision on an abatement system depends on the pressure, temperature and chemical composition of the geothermal fluids.

But if reinjection works for Ormat, says Moss, True Mid-Pacific will consider it.

"If it works here, it could probably end up being the best available control technology for the non-condensable gases," he says.

Advertiser photo by Bruce Asato

True Geothermal project coordinator Allan Kawada points to the teeth on a drill bit at the firm's rig in Puna.

Hydrogen sulfide: A primer

Here's what the experts say about exposure to hydrogen sulfide, a gas emitted from geothermal wells on the Big Island. The numbers generally refer to one-hour averages of exposure:

- Background levels at Kilauea — 1 to 3 parts per billion.
- Half the human population can smell it at 5 parts per billion.
- Federal OSHA standards for exposure of geothermal workers — 10,000 parts per billion for 10 minutes.
- Possible eye irritation — 10,500 to 21,000 parts per billion.
- OSHA requires workplace evacuation — 47,000 parts per billion.
- Respiratory distress — 500,000 to 700,000 parts per billion.
- Rapid death — 1,500,000 parts per billion.

The day the creek ran 'milky white'

Problems with The Geysers could serve as lesson for Hawaii

By Jim Borg
Advertiser Science Writer

5-15-90

MIDDLETOWN, Calif. — Voris Brumfield glanced up from her kitchen sink at an unusual and alarming sight.

"I was washing dishes, looking out my back window, and the creek turned white, milky white," she recalls.

The year was 1979 and Brumfield, a resident of the mountain forest community of Anderson Springs, population 275, suspected immediately that the source of the pollution was the nearby geothermal energy field at The Geysers.

In fact, the creek was flooded with drilling mud, overflow from a drill rig's waste-water holding pond. The water, she was told, was white from the bentonite clay used in the drilling process.

Only later did she learn that Anderson Springs got part of its drinking water from that same creek.

Dotting a series of mountain ridges and canyons 75 miles north of San Francisco, The Geysers is the world's largest natural-steam energy field, with an installed capacity of 1,900 megawatts, enough to run the state of Hawaii.

While geothermal plants are expensive to build, they have a number of advantages over traditional power generation plants. The fuel supply is cheaper and the cost to the environment is far less than with plants that burn oil or coal.

Brumfield

Yet geothermal development at The Geysers has suffered some serious growing pains. Local officials say there are some important lessons here for Hawaii, where geothermal energy is at a critical threshold.

The environmental headaches have included smelly sulfur emissions, toxic chemical spills from truck accidents, and ear-splitting noise from steam shooting up through the drilling rigs.

But today the problems are all but gone.

"The industry is coming out of its infancy," says Brumfield. "I feel they have done an admirable job. There are errors, there are mistakes. There are human beings running the show."

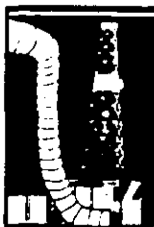
Under California law, counties bear much of the responsibility for issuing permits for geothermal projects up to 50 megawatts and for monitoring compliance with environmental regulations. Larger plants must get permits from the California Energy Commission, but the process has room for formal participation by the public.

Since the day the creek turned white, Brumfield has been one of the most energetic and vocal watchdogs of geothermal development at The Geysers. Eventually, the residents of Anderson Springs became official parties to the planning process for Pacific Gas & Electric Co.'s 135-megawatt unit 13, about a half-mile up the canyon.

"Our primary goal was to have them move the plant," says Brumfield, who in 1984 parlayed her activism into an elected seat on the Lake County board of supervisors. "We did not succeed in that. But a lot of our secondary goals were met."

Among the concessions: geothermal developers contributed to a new $1.2

See Geysers, Page A4



KILAUEA RIFT:
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Today:
Fumes of burning stone
Lake County's growing pains

Tomorrow In The Advertiser:
In the ahupua'a
High tech in the high desert
Invasion of the mud volcanoes

Geysers: Woes could be object lesson for Isles

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million domestic water system for Anderson Springs.

"Our intention was not to stop the industry by any means, but to make sure they were coping with the people who were living here and not impacting the community," says Brumfield. "And not screwing up the water."

Mark Dellinger, geothermal coordinator for Lake County, which now has five plants capable of generating 425 megawatts, says the relationship between the geothermal industry and local residents has improved dramatically from the days of "Wild West" style confrontation.

"The incidence of spills has been going down as we've all become much more aware of these materials and waste," says Dellinger. "I think everybody's more cautious."

Dellinger has not visited Hawaii's geothermal fields, but says many Hawaii business and government leaders have stopped in to see him over the last few years. "From what I have seen and heard in Hawaii, with all of the protests and issues — to be honest with you, it wasn't all that much different when it started back here in the early to mid-'70s," he says. "It takes a while to go through the learning situation."

Says Bob Reynolds, air pollution control officer with the regional air quality management district: "Initially, there were a lot of problems. There was a really bad situation, a lot of opposition, a lot of lawsuits, and it took about six or seven years to square it away."

With the geothermal industry now mature, most problems can be prevented with new technology and redundancy in the steam-flow systems, says Reynolds, who is also responsible for monitoring compliance with noise standards.

"In terms of noise, they've got about 95 percent of it licked," he says. "Air quality, I'd say we're approaching 98 percent."

When geothermal wells tap underground pockets of steam and hot water, they also bring up a number of noxious chemicals and metals, including hydrogen sulfide — the nauseating "rotten eggs" smell — boron, arsenic, silicon particles and fluorides.

In the last three years, there have been no hydrogen-sulfide emissions exceeding the standard of 25 parts per billion, says Reynolds.

Drill rigs can also carry up whatever metals might exist in the intervening rock. And the noise produced by venting a steam well is notoriously loud.

"When they would hit steam, it would sound like a 747, except it never went away," recalls Brumfield. "It would roar for six, seven hours."

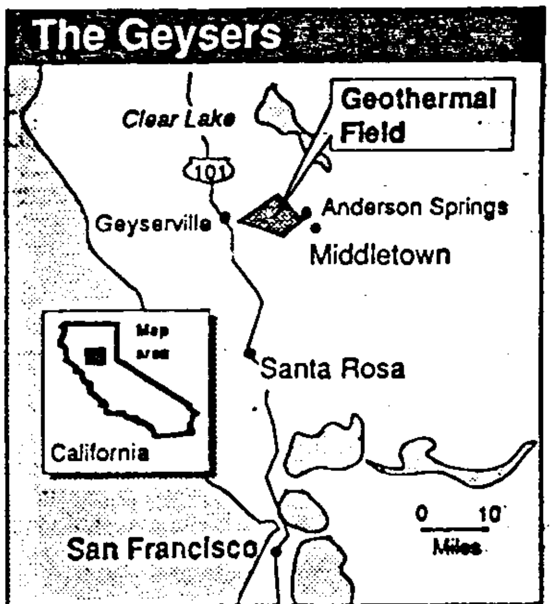
Boyd Lane Jr., an Anderson Springs resident and former oil-well driller who attended Pearl Harbor Elementary School from 1956 to 1961, said the noise problem was worse than any sulfur smell. "It was terrible," he says. "You couldn't sleep some nights, like on a calm spring evening. It's the kind of sound that makes people grind their teeth."

Reynolds says permits have forbidden routine unmuffled venting of steam for eight or nine years.

"That is not to say it doesn't happen with accidents or on rare occasions," he says.

At its newest rig, Unocal has placed lead shielding around the drilling pads to keep the industrial noise from drifting down to Anderson Springs.

Noise also can be reduced by avoiding direct-drive generators mounted up on the rig deck, where the height allows sound to travel farther, says Reynolds. Drillers



Advertiser graphic by James Takamiya

now routinely keep the generator low to the ground and muffled and run batteries off it to power the rig, he says.

"In the last year and a half, (the bothersome sounds) have gotten less," says Lane.

Another problem that has been solved is the release or "stacking" of unfiltered steam into the air when the power plant suffers a shut-down.

"The real problem with a geothermal power plant, unlike any other air emission source, is, when they break down, you can't just shut off the steam," says Reynolds.

The newest plants have bypass systems that route the steam around the turbine but through the plant when it is shut down, rather than sending it directly up a stack. "Instead of stacking, you run the steam through the abatement systems," says Reynolds.

Nearly all plants now can shunt their steam to a second turbine or another plant in the same field, Reynolds said.

The operators take steps to prevent soil erosion and also to replant native vegetation once the wells, pipes and generating houses are in place.

"I'd say in general they are doing pretty well," says Dellinger. "As regulators and compliance monitoring people, we have gone through a learning curve as well as the industry. And it has taken a while to learn from each other and learn what is possible and what may be possible in the future.

"You can find a whole school of people out there who are not happy with geothermal development, but if we have a credible enforcement and compliance monitoring program, it becomes more acceptable to them."

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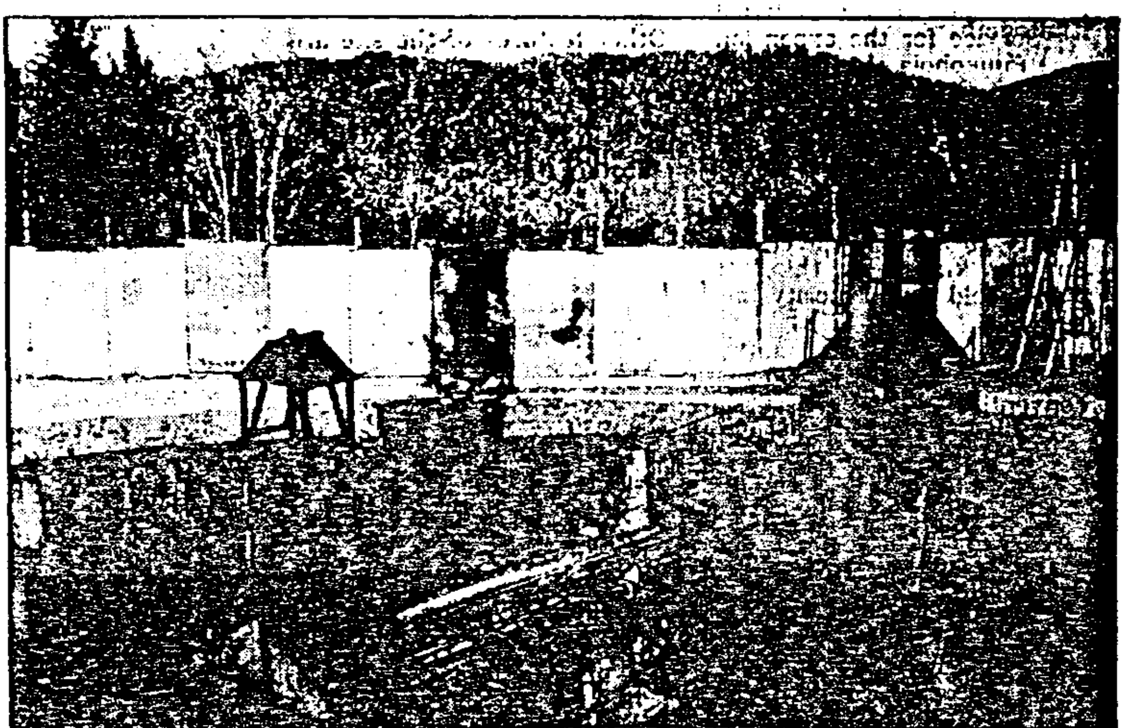

Advertiser photo

A drilling rig sump at The Geysers, with noise baffles in background.

Geothermal debate finds new fuel in rainforest preservation issue

Last in a series

5-16-90

By Jim Borg
Advertiser Science Writer

PAHOA, Hawaii — For 60 years, Henry Auwae has been gathering medicinal herbs in the Wao Kele O Puna rainforest.

Auwae, 79, who lives in Keaukaha outside of Hilo, is a Hawaiian herbal medicine doctor, or kahuna la'au lapaau.

His practice depends on his access to the forest of the ahupua'a, a traditional land division extending from the mountain to the sea. The ancient rights of native Hawaiians in these undeveloped areas have been affirmed by the state Constitution.

Auwae gathers pink opiko to make tea for women who have had miscarriages. He finds true koli, the castor bean plant, useful in the treatment of diabetes.

"Wao Kele O Puna produces these plants with a quality and potency I have found nowhere else," says Auwae, who last year went to Washington, D.C., at the invitation of the Smithsonian Institution to share his knowledge.

But since the True/Mid-Pacific geothermal enterprise began bulldozing the forest to clear an eight-acre drilling site last fall, Auwae says he has become concerned about the future of his natural-medicine chest.

"Much opiko had been uprooted," he said after one visit. "Also knocked down were the koli and pa'iniu. Due to the difficulty I encounter in finding these plants, I was very disturbed by this destruction. I also saw knocked down medicinal plants and trees which take many years to grow . . . "

Auwae in February made his objections known in an affidavit to the U.S. 9th Circuit Court of Appeals.

A lawsuit by the Pele Defense Fund challenged the 1985 decision by the state Board of Land and Natural Resources that allowed the state to swap its Wao Kele O Puna property, a natural area reserve, with land owned by the Campbell Estate in Kahauale'a, nearer Hawaii Volcanoes National Park.

While residents in the Wao Kele

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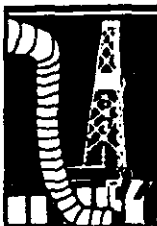


KILAUEA RIFT:
The Geothermal Power Struggle

Today: In the ahupua'a
On Page A8:
- High tech in the high desert
- Invasion of the mud volcanoes

Henry Auwae, at home in his medicinal garden outside Hilo.

Geothermal: Fear of destruction propels foes

FROM PAGE ONE

ahupua'a kept their gathering rights. Campbell Estate hopes to develop extensive geothermal-energy fields in the part of the forest designated as the Kilauea middle east rift geothermal resource subzone.

On May 4, the San Francisco-based 9th Circuit Court upheld a lower court ruling sanctioning the exchange.

Forests are good for at least two reasons: for the wealth of plants and animals they embrace, and because plants cleanse the air of carbon dioxide, a suspect in possible global "greenhouse" warming.

While many Americans are concerned about the slash-and-burn destruction of the Amazon rainforests of Brazil, the situation on this southeast slope of Kilauea Volcano is certainly less severe.

Hawaii, the fourth smallest state, ranks seventh highest in state-owned forest lands, totaling 900,000 acres, with another 270,000 acres in national parks and wildlife refuges, and 29,000 acres under sole or shared management of The Nature Conservancy.

But there's a more disturbing perspective. Hawaii's lowland rainforests have been chopped to about a tenth of their presettlement extent, estimates Jim Jacobi of the U.S. Fish and Wildlife Service's Mauna Loa research station.

The question of the remaining forest's intrinsic value is open to debate.

A biological survey of the forests in Puna was completed in 1985 by the University of Hawaii botany department for the state Department of Planning and Economic Development.

Leading the team was botanist Charles Lamoureux, associate dean for academic affairs in the UH Colleges of Arts and Sciences. Building on work by the U.S. Forest Service, Lamoureux placed the landscape into several categories based on vegetation, ranging from pristine ohia forest to barren lava flows.

Lamoureux concluded that geothermal development could

Charles Lamoureux
Led biological survey

indeed destroy native habitats, but that the most abundant tracts of pristine ohia forest were in the new state land, swapped with the Campbell Estate, at Kahauale'a, far from the Kilauea geothermal subzone.

He defines pristine as "a more or less intact wet native forest community" — closed canopy forests with lower layers of other native trees, tree ferns and shrubs. Introduced exotic plant species are rare in these areas, except where they have been established by rooting pigs, he says.

Nearly all of the forest in Wao Kele, where the geothermal subzone is situated, is a wet ohia forest underlaid by foreign shrubs, primarily strawberry guava, says Lamoureux.

Wao Kele certainly qualifies as a lowland tropical rainforest (below 3,000 feet in elevation, more than 100 inches of rain per year, and more than 50 percent native canopy cover). In all, the state Division of Forestry and Wildlife lists nine other such forests on five islands. However, the 27,000-acre Wao Kele tract is part of the largest single expanse of U.S. tropical rainforest, totaling 60,000 acres.

The state estimates that development of 100 megawatts of power on Kilauea's middle east rift would mean razing 350 acres, about 1.3 percent of Wao Kele and about 0.6 percent of the entire Puna lowland forest.

Installing plants to provide 500 megawatts to Honolulu would require proportionately more cutting.

Everyone agrees that roadways between drill sites and power plants will create avenues for the migration of even more foreign species, since every vehicle can carry seeds in on its tires.

The Campbell Estate says the roadsides will be inspected periodically and exotic interlopers will be dosed with herbicide. Environmental groups say they doubt this botanical border patrol will catch every alien.

While no one disputes Lamoureux's conclusion about the near-pristine nature of Kahauale'a forest, much of which is over 3,000 feet in altitude, others argue the Puna forest ecosystem should be considered as a whole.

Says Nelson Ho, regional vice president of the Sierra Club: "What we've got is one botanist isolating one chapter in the book of the rainforest and saying, 'There are better pieces of literature than this. Let the developers do what they want.'"

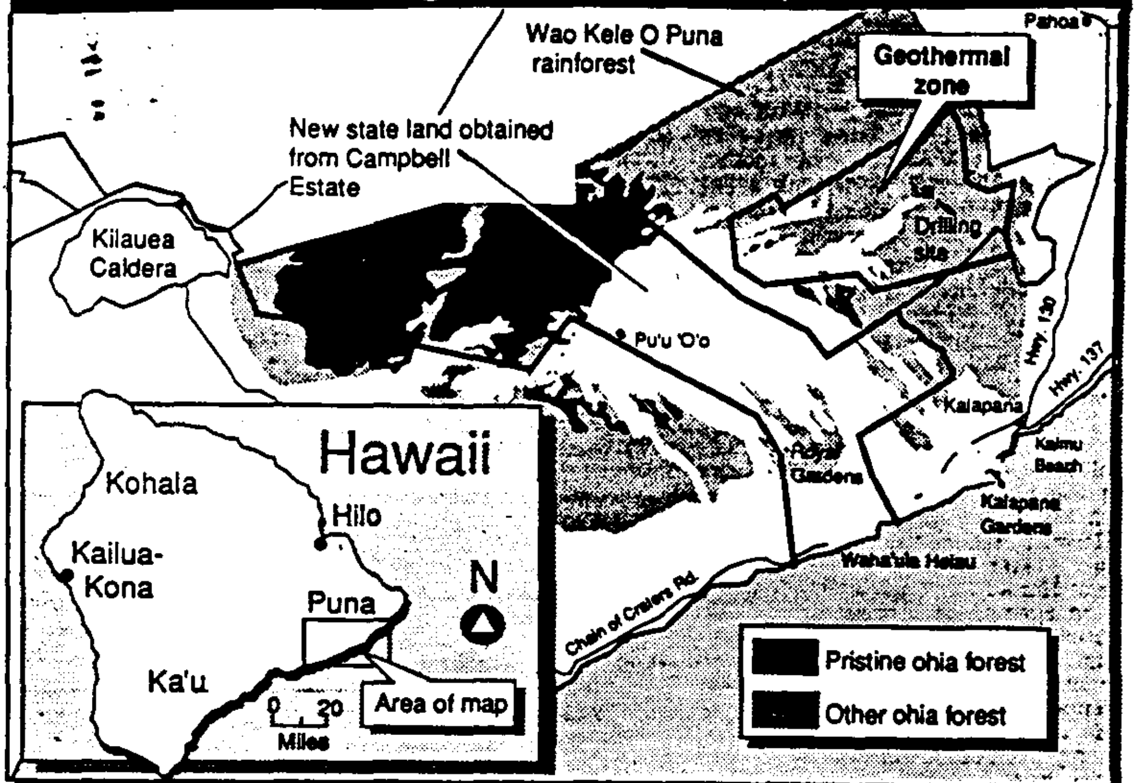
"My general feeling is none of these areas warrants sacrifice," says Dan Taylor, chief of resource management at Hawaii Volcanoes National Park. "They might be weedy and somewhat degraded, but any forest that gets cleared never comes back."

UH botany professor Dieter Mueller-Dombois argues that an important measure of a Hawaiian forest's value is its ability to re-colonize lava flows. In this process ohia is particularly adept and strawberry guava and other alien invaders largely irrelevant, he says.

"I agree pristine forest is extremely valuable, but the question in this particular situation is whether there is still enough native vegetation around to reinhabit the new lava flows," says Mueller-Dombois. "A forest is not a static unit that sits there and has no other function but to remain pristine."

The Wao Kele forest is also important for studies of the evolution of kipukas, oases of forest in the lava desert, biolo-

The ohia forest and geothermal development



SOURCE: KILAUEA, The Newest Land on Earth—Bishop Museum Press

Advertiser graphic by Greg Taylor

The state land at Kahauale'a, obtained from Campbell Estate, contains Puna's best-preserved tracts of ohia, far from True/Mid-Pacific site, shown in this map based on Lamoureux survey.

gists say. Since the land swap, lava flows have wiped out much of the lower Kahauale'a forest and the small areas of pristine ohia found in the middle east rift geothermal subzone.

What about birds?

The Lamoureux team's ornithologist, Andrew Berger, concluded: "Only a few endemic forest bird species inhabit the forests of the east rift zone of Kilauea Volcano, and their populations are low in comparison to their numbers at higher elevations. None of these endemic forest birds is considered to be endangered or threatened with extinction."

A small number of Hawaiian hawks occupy the east rift zone range, Berger said, but they range far enough to avoid any objectionable effects of geothermal development.

Sheila Conant, UH associate professor of general science and a research associate at the Bishop Museum, disagrees. Conant, who has studied the ecology and breeding biology of Hawaiian birds since 1964, says roads and noise will have a serious effect on the bird populations.

"To suggest that birds could 'move away' from an immediate source of danger or irritation is unrealistic," she says. "If the birds can move away before they are killed, they will be forced to move either to an unsuitable habitat or to a habitat which is already occupied by members of their own species. In either case, the individuals that move have little chance of survival because the resources they require will not be abundant enough to support them."

For Hawaii's energy planners, who hope to reduce the state's dependence on fossil fuels, Conant's scenario for Wao Kele's displaced birds has a familiar ring.

What will Hawaii's growing population do when oil for electricity is no longer abundant?

The arguments over geothermal energy in Hawaii ultimately may be refined to a painful trade-off between finite natural resources — the living legacy of Wao Kele and the geological remnants of long-dead forests we now import as fuel.

Judging from recent protests, much of the opposition to geothermal development may be focused against industrialization of any kind in the relaxed, rustic Puna district. Residents understandably may not want to see their lifestyles sacrificed on the altar of air-conditioned Honolulu high-rises.

Then again, trees and birds don't vote.

"I think the protests will continue," says state Sen. Andy Levin, D-1st District (Kailua-Kona-Ka'u-Puna). "I think the development will continue."

5-16-90

Coso geothermal project walks thin line

A path between Navy ballistics, a fragile desert and arrowhead sites

By Jim Borg
Advertiser Science Writer

CHINA LAKE NAVAL WEAPONS CENTER, Calif. — Several times a month, the crews that run the Coso Geothermal Project get up and walk off the job.

The evacuation is required by the Navy, which operates an elaborate ordnance-testing range in this 3,000-foot-high corner of the Mojave Desert.

No one wants a stray cruise missile to claim lives as well as property.

For two or thee hours at a stretch, Coso's high-tech steam turbines spin under the guidance of computers. When the range reopens, the crews return and pick up where they left off.

"We designed the plant so it could operate itself and shut itself down if something goes wrong," says Lee Ezzell, vice president for plant operations with California Energy Co., the Coso project developer. "Any alarm goes off, it shuts down."

Perched on an ancient network of seismic faults between the Sierra Nevada and Coso mountains, the $615-million operation since January has been churning out 240 megawatts of electricity for Southern California Edison. This is now the second-largest commercial geothermal field in the United States.

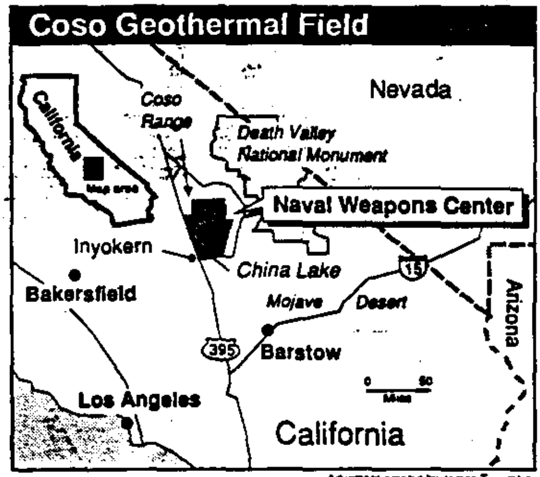
California Energy Co. and its engineering and construction contractor, Mission Power Engineering Co., are members of Kilauea Energy Partners, one of two groups negotiating with Hawaiian Electric Co. for possible development of 500 megawatts of geothermal energy on the Big Island.

While the Mojave's subterranean soup may be markedly different from the geothermal resource beneath Kilauea, the basic technology for harnessing hot water and steam remains the same.

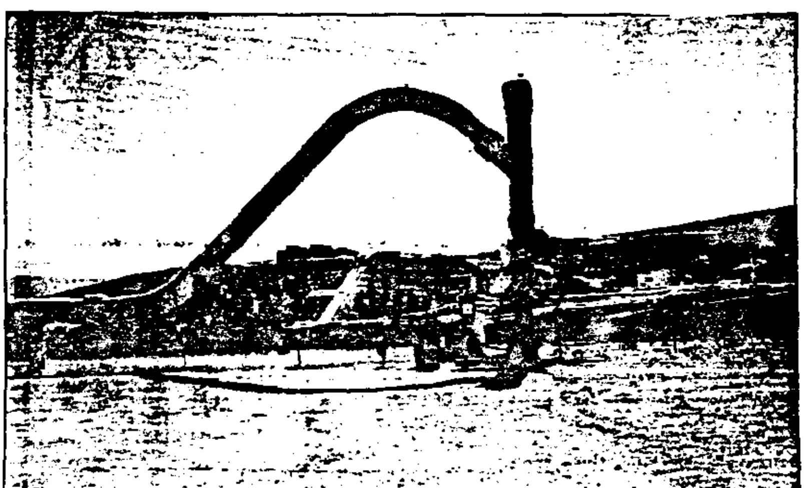
"New Zealand, Italy, Japan, the Philippines, Central America basically all have similar conditions," says Ezzell, who has also worked at the Pacific Gas & Electric geothermal field at The Geyers in northern California.

And while Coso is not the only geothermal plant run at times by computers, it has become a model for the industry for its relationship with the fragile desert ecosystem and its technique for dealing with the dark side of the geothermal force: hydrogen sulfide.

Through 61 wells ranging up to two miles deep, the Coso project taps pressurized 400-degree water fed by mountain runoff. Only three shallow wells produce from a steam



Advertiser graphic by James Tasamiya



Advertiser photos by Jim Borg

A geothermal production well feeds Coso's Navy-1 plant in the Mojave Desert.

reservoir.

The nine Coso generators use a "double flash" system of geothermal power production, meaning steam separates from water twice at different pressures. The water that cascades from the plants' cooling towers — the noisiest part of the operation — then is reinjected through wells penetrating deep into the ground.

Since Coso is a water-dominated system, as are Kilauea's geothermal zones, it hasn't had the problems with water reinjection experienced at The Geysers in northern California, a reservoir of almost pure steam, where sharp temperature differences have damaged some injection wells.

Toxic hydrogen sulfide gas is reinjected along with the condensed steam and waste brine.

"We put the gases back in the water and put it all back in the ground," says Ezzell. "We end up with a cleaner system."

Adds Cal Energy's environmental compliance technician, Jony Homer, "We don't put anything into the air but water vapor."

In terms of cleanliness and plant safety, geothermal power has huge advantages over every other form of power generation except hydroelectric, says Sean Maney, the 28-year-old supervisor of Coso's Navy-1 plant.

"I don't have a boiler, I don't have a reactor plant," says Maney. "All I've got is some hot water coming out of the ground. We're the original plant that recycles everything that's produced in the field."

Although the project is on federal land, the developers comply with the environmental requirements of the California Energy Commission and California Department of Fish and Game.

Bob Haussler, manager of the commission's environmental protection office in Sacramento, gives high environmental marks to Coso in particular and geothermal energy in general.

During drilling and construction at Coso, the commission was concerned about the effects on archeological sites, Haussler says. Some 6,000 to 7,000 years ago, native Americans flocked in great numbers to the desert, where they collected and fashioned obsidian, a dark volcanic glass, into knife points and arrowheads.

Cal Energy agreed to preserve as many sites as possible and catalog those that had to be disturbed, says Haussler.

"I'm not aware of any violations," Haussler said in a telephone interview.

To an unschooled eye, the Mojave may seem a wasteland, but biologists know better.

The desert supports a treasure house of animal and plant species, some of them, like the joshua tree and desert tortoise, endangered.

The company has gone as far as to dig up and relocate an entire den of state-protected mojave ground squirrels, says Homer.

Workers also routinely rake up tire tracks that would otherwise mar the desert surface for a decade, he says.

"One of the real challenges is going to be ensuring that for the long-term we are able to keep all those balls in the air," says retired Maj. Gen. Mark Sisinyak, the Coso project's general manager and a 32-year veteran of the Army Corps of Engineers. "It helps to know how the federal bureaucracies and state bureaucracies work."

A lone joshua tree stands amid pipes and power lines on the Navy testing range.

Tribes turn up the heat on hot-springs change

CHINA LAKE NAVAL WEAPONS CENTER. Calif. — In this dry and rugged country, home of the desert kit fox, mojave ground squirrel and cottontop cactus, California's newest geothermal energy field coexists with nature, the Navy and hundreds of Native Americans.

The coexistence is not always peaceful.

In late March, the Paiute-Shoshone Council, representing 1,060 members in seven tribes in California and Nevada, offered up its latest protest to the just-completed $615-million Coso Geothermal Project.

Earlier this year, the last of nine generators came on line at the Coso project, developed by California Energy Co.

At issue is the Coso Hot Springs, located in the heart of this huge and hush-hush weapons-testing range.

For the Indians, the hot springs hold religious significance much the same way that volcanos are important to some people in Hawaii as a manifestation of the ancient goddess Pele.

The Coso springs have been the focus of medicinal pilgrimages since prehistoric times and in 1976 were designated a national historic site.

"We'd use the mud for ailments, as a salve," says Sandra Jefferson Yonge, tribal leader of the nearby Lone Pine Indian Reservation, home to 235 native Americans. "We'd use the steam for sweat purposes, a medicinal type of activity . . . You can't separate religion and your medicine and the Earth."

But now the springs are changing — sprouting hotter-than-normal steam and mud volcanoes — and the council blames the adjacent geothermal plants, also on Navy land.

"The site has been desecrated," says Yonge.

At the Navy's request after the tribes' initial protest last year, California Energy paid a consultant to look at the problem to determine if the reinjection of geothermal fluids from the Coso plants could account for the changes at the springs.

The conclusion: it could not.

Unsatisfied, the tribes asked for a review by two geothermal scientists who found the consultant's report "substandard," said Yonge.

Now she's asking the Navy to kick in $60,000 so the council can commission its own study.

If a second study finds the Coso project at fault, "we fully expect that the Navy will enforce its contract with California Energy Co. to implement a mitigation plan to lessen, if not eliminate, the destruction and desecration of Coso Hot Springs," says Yonge. "The heritage of all Americans is at stake here."

California Energy officials say the Coso Hot Springs are most likely undergoing natural changes typical of centuries-long cycles of geothermal activity.

— Jim Borg

5-16-90

STATE OF HAWAII

GEOTHERMAL ACTION PLAN

ELEMENT II

REVIEW OF EMERGENCY PLAN AND RESPONSE TO THE 12 JUNE 1991 UNCONTROLLED VENTING OF THE PUNA GEOTHERMAL VENTURES (PGV) KS8 GEOTHERMAL WELL

SUBMITTED TO: The Honorable Lorraine R. Inouye
Mayor of Hawaii County
25 Aupuni Street
Hilo, Hawaii 96720

The Honorable John C. Lewin, M.D.
Director of Health
State of Hawaii
Department of Health
1250 Punchbowl Street
Honolulu, Hawaii 96813

PREPARED BY: J. Mark Ingoglia, M.P.H., Manager
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DATE: July 18, 1991

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EXECUTIVE SUMMARY

The actual implementation of the PGV Emergency Response Plan went reasonably well. Concern from fire and police personnel over health risks and confusion on the part of citizens over how to proceed during the on and off again alert notification in the Leilani Estates Subdivision were a cause for some difficulty during the response. Confusion over the applicability of temporary housing cost reimbursement in relation to the 3,500 feet perimeter and the function of the PGV Employee Alarm System also served to exacerbate the stressful nature of the emergency response to the blow out. Nonetheless, the evacuation and alert were successful.

Based on the experience of the 12 June 1991 upset incident, the PGV Emergency Response Plan should be reviewed and revised appropriately. Such a review should henceforth be conducted annually, along with exercising the plan.

The Pahoa Community needs to understand how these issues are resolved so there is no confusion in the event of another upset. Emergency air monitoring, concern over emergency H_2S action levels and PGV emergency notification are other areas that require review and improvement.

The following summary recommendations are provided based upon a preliminary review of the 12 June 1991, response to the PGV well blow out:

1. The Department of Health (DOH) should complete a revised analysis of the hazard of an uncontrolled venting of the PGV Well.

2. DOH should complete a health review of the warning, alert, and emergency action levels for H_2S.

3. DOH should complete a review of H_2S monitoring capability and procedures for upset conditions.

4. Upon completion of 1 through 3 of the above, the Hawaii State Emergency Response Commission and Hawaii County Local Emergency Planning Committee should review, revise and exercise the PGV Emergency Response Plan.

5. The Hawaii County Planning Department should resolve confusion over housing reimbursement and the function of the PGV employee alarm system.

6. PGV should review notification procedures and provide appropriate verbal and written notification to ensure compliance with the Emergency Planning and Community Right-to-Know Act of 1986.

I. BACKGROUND

In July of 1990, after seven months of review, the Emergency Response Plan for the Puna Geothermal Venture (PGV) 25 MW Power Project Geothermal Resource Permit: GRP 87-2 was accepted by Hawaii County and Hawaii State government agencies to fulfill permit requirements. Approximately one year later at 11:06 p.m. on 12 June 1991, an uncontrolled flow event at the PGV Well activated the Emergency Response Plan. During the approximately 31 hours of the release, PGV, County and State agencies, and volunteer organizations worked with citizens to respond to the release, evacuate households in the Lani Puna Gardens, alert residents in the Leilani Estates Subdivision and, provide shelter and security, while the release was being brought under control.

Another important factor in the response was conflicting information that may have caused confusion. During and after the response, questions by citizens were raised over reimbursable costs for emergency response, the function of the PGV alarm, and the general applicability of the 3,500 foot perimeter as defined in the Geothermal permit, and other issues that relate to this incident. For example, under the permit, PGV is required to reimburse community members that must be relocated for a controlled venting if they are within the 3,500 foot perimeter. PGV is not required to reimburse community members for relocation costs for uncontrolled venting during emergencies, etc.

PGV has an employee alarm system at their facility for their own emergency use. The alarm is not meant to be used by citizens for their notification purposes. Nonetheless, a number of citizens have expressed concerns that they did not believe that the alarm system worked properly so that they were notified of the emergency. Other citizens have noted that PGV did not use the alarm in all events when they should have.

Finally it should be noted that the PGV Emergency Plan had never been exercised and this is the first time a geothermal release has prompted an evacuation in Hawaii. Therefore, this is the first time the emergency response plan has been evaluated based on an exercise or an actual experience and affords an opportunity for PGV Emergency Response Plan improvement.

II. REVIEW OF RESPONSE AND DISCUSSION

A. Sequence of Events

A brief review of the essential sequence of events that occurred during the response is included in Appendix I. It is not complete, but provides a general outline of the key events that occurred. A summary of Appendix I is provided below.

Wednesday, 12 June 1991

- At 23:06 PGV reports the well blow out occurred. At 23:15 a citizen notified Hawaii Fire Department (HFD) of a possible Geothermal venting or upset event. HFD immediately notified Hawaii Civil Defense (HCD). PGV contacted HCD at 23:25. At 23:34 PGV requested HFD provide an ambulance for two minor injuries. At 23:45 Hawaii Police Department (HPD) reported a 60 foot steam cloud from the Well, wind coming from the southeast and headed for the Pohiki area.

- At 23:30 HPD arrived on-scene at the pre-designated command post, a third of a mile east of the Well head.

- At 23:55 HCD requested Department of Health (DOH) hydrogen sulfide (H_2S) monitoring support. DOH estimated a time of arrival to the command post at 01:30.

Thursday, 13 June 1991

- At 00:10 HPD commenced evacuation of Lani Puna Gardens based on recommendation by PGV. HFD noted that they were not notified of this event. HCD noted that this was due in part to the fact that the evacuation was for a small number of households (5).

- At 00:50 HCD contacted HFD at the Emergency Operations Center, Hawaii Civil Defense Agency, Hilo, Hawaii.

- At 00:50 HCD contacted the Red Cross to open the shelter at the Pahoa Community Center based on the Lani Puna evacuation.

- At 01:00 PGV reported first monitoring data just outside the fence line of the perimeter of the well site, 20 parts per million (ppm) of H_2S, and a second reading 29 ppm of H_2S.

- At 01:10, DOH monitoring staff contacted the Deputy Director for Environmental Health, who recommended proposed H_2S action levels be used as guidance in protecting public health. It was recommended that the residents be relocated if H_2S levels are likely to exceed 10 ppm as a one hour average.

- At 01:25 DOH monitoring from Lanipuna Street reported less that .5 ppm H_2S (the limit of detection for the Dreager tube being used).

- At 01:13 a house-to-house alert was initiated by HFD as requested by HCD. This alert was for the 230 homes in the Leilani Estates Subdivision. These are approximately one-acre lots and the houses are spread far apart, therefore it took a substantial amount of time to notify each household.

- At 01:30 the Red Cross reported that the Pahoa Neighborhood Center Shelter was open and, at 01:37 roadblocks were established by HPD at three points to control traffic near the effected area.

- At 02:15 HCD requested HFD to stop the house-to-house alerts in the Leilani Estates Subdivision. This decision was based on the determination that the situation required reevaluation and a review and coordination of the alert message that was being provided to the Leilani Estates Subdivision residents by HFD.

- At 05:00 HCD notified all radio stations of the Alert Advisory Status of surrounding residential areas for any individuals that may be experiencing any unacceptable nuisance or health effects from the release and that persons should report to the Pahoa Neighborhood Center. A copy of the announcement is attached in Appendix B. At 05:15 HCD, based on their reevaluation, determined that the uncontrolled venting would be prolonged and that the house-to-house alert should be continued. At 09:15 the house-to-house alert was completed.

<u>Friday, 14 June 1991</u>

- At 06:30, PGV reports the well had been shut in.

B. Release Notification

At 23:06 PGV reports that the uncontrolled flow event began. PGV then notified HCD at 23:25. Therefore, estimated time required for PGV to notify response authorities initially was approximately 19 minutes. During this time, PGV reports that they were moving injured workers away from the drilling rig and securing the immediate area around the rig.

Notification of releases of H_2S above the reportable quantity (RQ) of 100 pounds in a 24-hour period should be provided to the National Response Center (NRC), State Emergency Response Commission (SERC), and the Local

Emergency Planning Committee (LEPC) under Section 304, Emergency Planning and Community Right-to-Know Act of 1986. By contacting HCD, PGV met notification for the LEPC. PGV requested HCD to contact DOH in order to comply with requirements for State Emergency Response Commission notification. PGV did not notify the NRC. As of 22 June 1991, the State Emergency Response Commission did not receive a written follow up notification of the H_2S release.

The release of H_2S most likely exceeded the RQ.

C. Site Response By PGV

PGV secured the site and only allowed authorized personnel to enter the site. PGV's site response based on limited information appears to have been conducted appropriately, at least in regards to security and coordination with agency personnel. Further evaluation of alternative technologies to control a well kick, and well venting in the event of an uncontrolled release should be conducted and is being pursued concurrently by a state funded team of experts.

It should be noted that for a certain period of time it has been reported that in order to control the well, the venting was directed horizontally, instead of vertically. Therefore, based on the PGV site response, a hazard analysis should include horizontal, as well as, vertical venting to determine more accurately the potential of H_2S concentrations that might be generated in the surrounding community from such a release.

HFD expressed concerns over the possible need for a rescue of injured personnel during a well head venting if a PGV rescue could not be conducted. Potential for personal protection equipment contamination from well steam indicates decontamination for first responders is also an issue. These concerns should be investigated further to determine the likelihood of this occurring, and appropriate planning completed based on this analysis.

D. Agency Notification

As described in Appendix I, it appears agency notification worked exceptionally well for this response, in that, HCD, HPD, HFD, DOH, and ARC were immediately notified in a timely manner and, based on distances to be traveled, responded to the appropriate locations in a timely fashion.

E. Public Alert Notification and Evacuation

Generally, public notification went well.

The high H_2S (20 and 29 ppm) concentrations reported at 01:00 supported HCD's decision to initiate alert notification procedures for residents in Leilani Estates. HFD implemented the alert notification in Leilani Estates 13 minutes after the HCD request. Eleven minutes later, at 01:25 DOH reported less than .5 ppm H_2S on Lanipuna Street. It appears that H_2S concentrations may have declined rapidly after the initial release.

Subsequent to the incident, citizens expressed concern over confusion as to exactly what was happening and where they should have been directed. Review of the verbal message provided by HFD staff conducting the house to house evacuation indicates that the reports were clear and appropriate.

Since the alert advisory of Leilani Estates was initiated at 01:13 it appears that the radio stations should have been notified of the advisory at this time. This may have reduced the amount of citizen confusion. At 05:00 HCD notified the radio stations of the evacuation.

The on again, off again nature of the alert advisory probably caused some confusion on the part of citizens. The alert was suspended from 02:15 to 05:15, a total of two hours. It should also be noted that HFD and HPD personnel expressed concerns about their potential exposure to H_2S during the evacuation and alert notification process.

The actual evacuation and sheltering was executed in a reasonable manner and was generally successful. American Red Cross personnel noted along with police and fire, that the persons that reported to the shelter had expectations for better provisions for the evacuees, such as blankets, ear protection, funds for temporary housing costs, and other support would be provided on-scene. Such arrangements had not been made. It should be noted that nationally, and in Hawaii such prearranged evacuation supplies are not stock piled at predetermined evacuation shelters due to the cost and the difficulty of knowing where an appropriate shelter location might be.

It appears that there is a variety of opinion on what should be provided to the citizens in the event of an evacuation caused by a uncontrolled geothermal venting release.

In addition, confusion on the part of many citizens as to what they are entitled to regarding reimbursement for cost associated with geothermal evacuation also led to high expectations.

PGV is not required to reimburse Hawaii County for emergency response costs in the event of an uncontrolled well venting. During the emergency, PGV was approached by a limited number of citizens at the command post for assistance in temporary housing costs because citizens needed money in order to rent hotels, etc. PGV did provide certain individuals with money so they could relocate during the emergency. This may have caused confusion because PGV provided funds for temporary housing costs despite the fact that they were not required to under the permit.

F. Emergency Air Quality Monitoring

Interviews and reviews of emergency monitoring data indicates that government emergency response monitoring capability is currently insufficient. In addition, health, police, and fire personnel indicated some uncertainty in understanding of H_2S hazards and methods for monitoring and detection.

DOH monitoring with Draeger Colormetric Tubes and utilizing a portable Colortec monitor were not completely sufficient for emergency response needs. Because of the stationary nature of the ambient air quality monitoring stations, these instruments can be considered supplemental to portable emergency response monitoring instruments.

A separate element of the review of this incident will evaluate the adequacy of the air and noise monitoring program.

There was a substantial delay between the original notification of the release at 23:25 and the first report of monitoring results at 01:00. Along with immediate health and safety issues monitoring should have been initiated and results reported in a timely fashion since H_2S monitoring is also an immediate health and safety issue when an upset condition occurs.

PGV monitoring was provided using a Jerome 631x monitoring unit which provides real time digital read out of H_2S concentrations. Real Time digital readout monitoring is more appropriate for emergency response needs and can be supplemented by an alarm type monitor that can be triggered if concentrations exceed a predetermined level. More appropriate monitoring instrumentation should be provided to health and fire personnel. Special consideration should be made for community wide DOH monitoring needs versus site entry, rescue, and safety monitoring needs of HFD.

G. Adequacy of Department of Health Alert, Warning and Emergency Action Level

It appears that there is still some concern as to the adequacy of the currently established Alert, Warning and Emergency Action Levels for H_2S as established under the PGV permit and included in the PGV emergency response plan.

Agency personnel as well as, many citizens certainly experienced a substantial nuisance from low concentrations of H_2S. Based on health effects reported, including headache, nausea, dizziness, respiratory irritation, and others, a re-evaluation of the emergency levels is indicated. It is important to note that well noise, stress caused by the incident, along with other pollutants in the venting steam may have contributed to the effect sensitive persons may have experienced from H_2S exposure.

It was reported that one police officer out of the four involved in the evacuation became ill from exposure to H_2S and therefore had to be pulled back from implementing the Lani Puna Gardens evacuation. Sensitive individuals have to be considered in the implementation of evacuation and the establishment of action levels.

H. Community Relations and Emergency Preparedness

Community relations is important in regards to the execution of an emergency response. Citizen cooperation and understanding is essential if a proper and efficient emergency response is to be implemented. Many citizens as well as agency personnel were confused the night of the emergency. This confusion would be minimized through a better understanding of the policies and procedures relating to the emergency response plan. Increased communication between PGV citizens and state and county agencies and non-profit agencies is required in order to improve the response. It should be noted that the Hawaii Planning Department did make the PGV Emergency Plan available for public review.

III. CONCLUSIONS

This limited evaluation identified a number of areas for response improvement. Other issues require further studies or a long term evaluation.

A fundamental element of a complete evaluation is a careful analysis of the actual concentrations of H_2S reported through out the PGV area and the surrounding community during the upset conditions compared to the modelled concentrations that were predicted in the emergency response plan. Generally, based on a preliminary evaluation of the data the concentrations of H_2S throughout the community were within the ranges of modelled or predicted values estimated in the hazard evaluation portion of the PGV Emergency Response plan. One exception stands out and that is the reported 22 and 29 ppm concentrations at the fence perimeter of the PGV facility.

Those high numbers supported the determination to follow through on the evacuation of Lani Puna Gardens, although the evacuation was initiated before monitoring results were received by HCD. It can not be assumed that the monitoring capability generally available in an emergency response will capture the highest concentrations of contaminants that actually occur during an emergency. This must be considered for planning, and response purposes.

Further investigation of monitoring data is required, and has already been initiated as a special study review of actual recorded data during the event, along with micrometeorological and aerometric analysis of the area surrounding the PGV facility.

This re-evaluation of the hazard may require a revision to the estimated hazard posed by a free flow venting of the well. A hazard analysis determines how an emergency response plan should be written and what resources should be prestaged for response and mitigation. Based on a revised hazard analysis, using all available information, the plan should be reviewed and revised appropriately. A review and if necessary revision of the plan along with exercising should be an annual activity in order to keep the plan operational and effective.

Emergency response monitoring capabilities need to be substantially upgraded. DOH and HFD personnel should be equipped to provide real time monitoring for their emergency response purposes. Redundancy in capability is required. PGV should establish procedures to begin monitoring and report results in a more timely fashion. The procedures should be addressed in the PGV plan. A separate study currently under way evaluating monitoring capability should expand on this issue and provide details on adequate monitoring capability.

PGV should evaluate its response capability for uncontrolled venting and should include capability to prevent and control any upset condition. PGV exceeded the RQ for H_2S under Section 304 of the Emergency Planning and Community Right-to-Know Act of 1986, and should complete additional notification as required. PGV notification procedures should be reviewed and revised to ensure complete and timely direct notification to all appropriate agencies.

If possible, public notification of an evacuation by radio should complement the timing for evacuations. This could serve to reduce confusion for evacuees, although awakening in the middle of a deep sleep to receive an evacuation or alert notice can be a cause of confusion in itself.

A complete review of the Alert Warning and Emergency Action Levels should be conducted by the DOH. Special consideration of low level nuisance effects on sensitive individuals is required. Upon completion of DOH's review of response levels, county and citizen representatives should be informed of DOH's findings and training provided to review how the levels should be used.

The actual implementation of the PGV Emergency Response Plan went reasonably well. Concern from fire and police personnel over health risks and confusion on the part of citizens over how to proceed during the on and off again alert notification in the Leilani Estates Subdivision were a cause for some difficulty during the response. Nonetheless, the evacuation and alert were successful. Based on the experience of the 12 June 1991 upset incident, the PGV Emergency Response Plan should be reviewed and revised appropriately. Such a review should henceforth be conducted annually, along with exercising the plan.

Confusion over the applicability of temporary housing cost reimbursement in relation to the 3,500 feet perimeter and the function of the PGV Employee Alarm System also served to exacerbate the stressful nature of the emergency response to the blow out. The purpose of these provisions in the permit should be revisited by the County Planning Department's committee that originally reviewed these issues. The Pahoa Community needs to understand how these issues are resolved so there is no confusion in the event of another upset.

The expectation of free hotel housing for some of the citizens may have played a role in the way the American Red Cross Shelter was received. Some individuals were expecting more than the standard, basic support than was provided at the Puna Neighborhood Center, and is provided nationally.

The following recommendations should provide a framework to improve the PGV Emergency Response Plan, reduce difficulties, and create a means for the public and private agencies, citizens and PGV to be better prepared for a well upset.

IV. SUMMARY OF RECOMMENDATIONS

A. DOH Should Complete a Revised Analysis of the Hazard of an Uncontrolled Venting of the PGV Well.

All emergency response H_2S monitoring data should be compiled and reviewed, and compared to initial modeling data. An analysis of the predicted H_2S hazard based upon the results of the actual field monitoring data should be used to complete a revised hazard analysis. The revised hazard analysis should be included in the PGV Emergency Response Plan. The analysis should address horizontal venting. This recommendation has already been initiated simultaneous to this emergency response review.

B. DOH Should Complete a Health Review of the Warning, Alert and Emergency Action Levels for H_2S.

The Warning, Alert and Emergency Levels for H_2S should be re-evaluated for their adequacy, particularly as they relate to nuisance levels and sensitive individuals. Other stressors such as noise, stress from the emergency and other pollutants in the well steam should be included in the review. A review and training on these and other pertinent levels should be provided to appropriate agencies. The review should also address the need for HFD rescue backup for PGV workers at the well site, and decontamination issues in the event of an HFD site entry.

C. DOH Should Complete a Review of H_2S Monitoring Capability and Procedures for Upset Conditions.

Emergency H_2S monitoring capability and procedures for county, state, and PGV should be reviewed, upgraded and revised as appropriate. This recommendation has already been initiated simultaneous to this emergency response review. Timeliness of PGV monitoring at the site should be addressed. Specific monitoring needs of DOH and HFD should be considered

D. The Hawaii State Emergency Response Commission and the Hawaii County Local Emergency Response Commission Should Review, Revise and Exercise the PGV Emergency Response Plan.

The PGV Emergency Response Plan, should be revised based upon 1-3 above. The plan should be updated by PGV and submitted to the Hawaii State Emergency Response Commission and the Hawaii Local Emergency Planning Committee on an annual basis. The plan should be exercised annually.

E. <u>The Hawaii County Department of Planning Should Resolve Confusion Over Housing Reimbursement and the Function of the PGV Employee Alarm System.</u>

The Hawaii County Department of Planning through its original committee that included community representation should revisit temporary housing cost reimbursement issues, the use of the PGV employee alarm system and applicability of the 3,500 perimeter as they pertain to the PGV permit. An effective education and information effort should be conducted to ensure the Pahoa community is aware of the final out come of this review.

F. <u>PGV Should Review Notification Procedures and Provide Appropriate Verbal and Written Notification to Ensure Compliance with the Emergency Planning and Community Right-to-Know Act of 1986.</u>

Amounts of H_2S released from the PGV well most likely exceeded the reportable quantity of 100 pounds which requires mandatory reporting. To ensure compliance, PGV should provide verbal and written notification to the appropriate agencies for this and any future upset conditions.

References

Puna Geothermal Venture, Emergency Response Plan Puna Geothermal Venture 25 MW Power Project Geothermal Resource Permit: GRP 87-2, April, 1991

U.S. Environmental Protection Agency, Federal Emergency Management Agency, U.S. Department of Transportation (1987) Technical Guidance for Hazards Analysis: Emergency Planning for Extremely Hazardous Substances.

Federal Emergency Management Agency, U.S. Department of Transportation, U.S. Environmental Protection Agency (1987) Handbook of Chemical Hazard Analysis Procedures.

U.S. Environmental Protection Agency, Review of Emergency Systems, Report to Congress, Section 305(b) Title III Superfund Amendments and Reauthorization Act of 1986. June 1988

Kizis, Thomas G. Report on Uncontrolled Flow Event as Per Conditions, #13 and #26. ATC No. A-833-795, Attachment II, Wellfield, June 17, 1991.

Doc#PVG791-HEEROfc.

APPENDIX I
Sequence of Events of 12 June 1991
Uncontrolled Geothermal Venting

TIME/DATE	ACTION/EVENT
Wednesday, 12 June 1991	
23:06	Well Blow out occurred.
23:15	Public notified Hawaii Fire Department (HFD) of possible Geothermal venting.
23:17	HFD notified Hawaii Civil Defense (HCD).
23:25	PGV notified HCD; HCD called out CD4.
23:30	HPD arrived on scene.
23:34	Puna Geothermal Venture Requested HFD for ambulance for two minor injuries at PGV. Meanwhile Hawaii Fire Department (HFD) arrives on scene.
23:35	HCD activated Emergency Operating Center (EOC). Opened operations in Hilo office.
23:36	HCD CD dispatched staff to predesignated command post.
23:40	HPD-Puna reported major blowout with steam cloud 60 feet high.
23:45	PGV reported 60 feet steam cloud from well, southeast winds headed toward Pohiki.
23:55	HCD requested Department of Health (DOH) monitoring support. DOH reports estimated time of arrival at command post of 01:30. HCD also requested another DOH personnel to report to the EOC.
Thursday, 13 June 1991	
00:10	Police commenced evacuation of Lani Puna Gardens based on PGV recommendation.
00:30	HCD arrives on scene brief by PGV, no H_2S, monitoring data reported from PGV.

00:50	HCD requested American Red Cross (ARC) to open Pahoa Neighbor Center (PNC) for temporary sheltering.
01:00	PGV reports first monitoring data from just outside fence line perimeter at well site. First reading 20ppm H_2S, second reading 29ppm. PGV requests HCD to notify DOH to meet notification requirements.
01:10	DOH monitoring staff contacts Deputy Director for Environmental Health who recommends proposed action levels by used as guidance to protect public health. Residents should be relocated if H_2S levels exceed 10ppm one hour average.
01:13	House to house "Alert Status" notification of the Leilani Estate Subdivision was initiated by HFD as requested by HCD.
01:25	DOH monitoring from Lanipuna Street reports less than .5ppm H_2S.
01:30	ARC reported shelter open at PNC; Fifty citizens registered. All agencies represented at the HCD EOC.
01:37	Road blocks securing the PGV well established by HPD at three points on request by CD.
02:15	HCD requests HFD to stop house to house alert in Leilani Estates Subdivision.
05:00	HCD notified all radio stations there was a voluntary evacuation notification and that persons should report to the PNC.
05:15	HCD determined the release would be prolonged and that the house to house alert should be continued.
09:15	HFD completed the house to house alert of Leilani Estates Subdivision is completed.

<u>Friday, 14 June 1991</u>

06:30	PGV reports well is shut in.

From : HAWAIIGEOTHERMAL/CABLE Sep. 18. 1991 05:33 PM P01

MP1013

JOHN WAIHEE
GOVERNOR
MURRAY E. TOWILL
DIRECTOR
BARBARA KIM STANTON
DEPUTY DIRECTOR
Takeshi Yoshihara
DEPUTY DIRECTOR

DEPARTMENT OF BUSINESS, ECONOMIC DEVELOPMENT & TOURISM

ENERGY DIVISION, 335 MERCHANT ST., RM. 110, HONOLULU, HAWAII 96813 PHONE: (808) 548-4080 FAX: (808) 531-5243

FACSIMILE TRANSMITTAL PAGE

PLEASE DELIVER THE FOLLOWING PAGES TO

NAME: State/County Geothermal (Janet Hill) (am Paty)

COMPANY:

FROM: Takeshi Yoshihara

DATE: September 18, 1991 TIME:

MESSAGE: The attached draft report to accompany the action plan is forwarded for your review prior to our Thruesday meeting (September 19, 1991 at 1:30 p.m.).

RECEIVED
'91 SEP 19 A10:54
DIV. OF WATER & LAND DEVELOPMENT

Total number of pages (including Transmittal Page): 12

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SEP 18 1991

GEOTHERMAL ACTION PLAN

Prepared by State and County Geothermal
Task Force

September 1991

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INTRODUCTION

A 31-hour blowout at Puna Geothermal Venture's (PGV) KS-8 well near Pahoa occurred on June 12 and 13. The blowout resulted in the evacuation of some nearby families and in numerous complaints of acute health symptoms from the released gases and the noise.

The blowout also raised a question as to whether or not the geothermal resource in the Kilauea East Rift Zone can be developed safely and without impacting the health of the nearby residents.

On June 16, immediately after the well was temporarily secured, the Directors of Health (DOH); Land and Natural Resources (DLNR); Business, Economic Development & Tourism (DBED); and the Governor's Representative met with their staffs to respond to the incident, identify what happened and recommend any changes to construction and regulatory oversight that might be warranted before development could be allowed to proceed. This group outlined a strategy for State and County officials which has since been followed.

INVESTIGATIONS

With joint State-County participation three concurrent investigations of the blowout were undertaken: A review of KS-8 well drilling equipment and procedures (Element I) conducted by 4 mainland government and private drilling, geologic and regulatory experts; A review of the emergency response procedures (Element II) conducted by the Department of Health and Hawaii County Civil Defense; and a review of air and noise mitigation, monitoring and enforcement (Element III) conducted by 2 mainland government and

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private engineering and regulatory experts. The final reports from the three groups were made available to the State and County on July 24, 1991. They were made available to the developer and the public on the following day.

A conclusion of the investigations was that the blowout did not occur as a result of "unusual or unmanageable subsurface geologic or hydrologic conditions." All three of the investigative reports recommended specific developer and government actions to minimize the potential for future adverse impacts on health and safety of personnel involved in the project and residents of nearby communities.

ACTION TASK FORCE

At the direction of the Governor and Mayor, a geothermal Task Force consisting of the Directors of DBED, DOH and DLNR; and the County's Managing Director, Planning Director and Civil Defense Administrator, assisted by their staffs, was established to develop a Geothermal Action Plan for implementing the recommendations of the investigative reports. Attachment A contains a complete listing of the Task Force and subcommittee members. The joint State-County Task Force has met at least weekly since mid-August.

The Task Force developed the following Overall Goal and Objectives, which have been diligently pursued in formulating the Action Plan described herein:

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OVERALL GOAL

To assure that geothermal development by Puna Geothermal Venture can proceed safely and without adverse effect upon the public health of the community.

OBJECTIVES

1) Determine what changes in Puna Geothermal Venture's drilling procedures, equipment, supervision, and regulatory oversight are necessary before drilling may proceed safely.

2) Determine what changes are necessary to improve Puna Geothermal Venture's emergency response plan as a result of the experience at well KS-8.

3) Determine what changes in our air quality and noise monitoring programs are necessary to assure public health is protected as a result of the experience at well KS-8.

On September 5, 1991 the Task Force received Puna Geothermal Venture's report on their own investigation of the blowout as well as PGV's response to the recommendations contained in the investigative reports. The Task Force believes that most of the actions recommended herein are acceptable to PGV which has already initiated its actions to assure compliance.

SUMMARY DESCRIPTION OF ACTION PLAN

Attachment B is the Task Force's recommended Geothermal Action Plan. It is organized in a manner corresponding to investigative

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Elements I, II and III. The plan addresses each of the investigative report recommendations, referencing the page(s) in the Element report on which each recommendation was discussed. The matrix indicates for each action item a due date based on practical estimates by the agencies affected, as well as the lead and, if indicated, support agency(s) involved. The Task Force believes that the due dates can be improved significantly through cooperative efforts between the developer and the regulatory agencies involved. It should also be noted that while an action item is logically to be completed by PGV, the Task Force believes the ultimate responsibility to carry out the plan should remain a regulatory function of the government, the agencies of which are identified in the plan. Additionally, the plan provides preliminary estimates of government resources required to carry out its responsibilities. Finally, the matrix includes PGV's remarks and an indication of the status of each task. The plan does not specify which tasks must be completed before PGV is allowed to resume development and further discussions will be held with the developer to determine those tasks.

Not addressed by the Task Force are several issues which were identified by State agencies such as relocation, royalty waivers and the Asset Fund. The Task Force believes that these issues do not have to be fully resolved prior to the resumption of construction. However, the Task Force believes that these issues must be resolved eventually.

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SUMMARY OF ISSUES

The Task Force believes that all Element I tasks relating to drilling equipment and procedures must be completed prior to resumption of activity. Based on PGV's submittal of September 5, 1991, many of these actions have been completed. They must, however, be verified by DLNR and the County. PGV must also receive DLNR approval to change certain wells already drilled from injection to production wells, and vice versa, before further drilling can resume. PGV cannot drill any new wells without DLNR approval of modifications to drilling permits and plans of operations previously approved. Finally, DOH and DLNR need to execute a Memorandum of Understanding relating to regulatory oversight of injection wells.

Element II addresses emergency response actions and plans that must be made before activity can resume. Many of the concerns which have been raised resulted from the confusion which arose during and following the blowout. Many of the actions required have been completed with one notable exception, the comprehensive review and modification, as appropriate, of PGV's Emergency Response Plan (ERP). The ERP, approved in 1991, is formulated around a worst-case scenario of anticipated emissions from the project. The plan further cites the levels of emissions that would trigger "warning", "alert" and "emergency" actions. The Task Force believes that the worst-case scenario and triggering levels of emissions need to be thoroughly reviewed (as confirmed by the analysis in Element III). The ERP must be appropriately revised by the developer, and approved by the County. The review and

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approval of comprehensive ERP is considered to be the "critical path" item that must be completed before PGV is allowed to resume drilling or proceed with any other activity where there is any risk of emission.

Element III consists of a review of air quality and noise abatement and monitoring recommendations. The Task Force believes that a number of Element III actions will require considerable time and resources to implement, particularly those that require long lead times for equipment purchase, obtaining funding and personnel. Health and safety of residents can be adequately safeguarded if the intent of these recommendations are fulfilled through several actions. Specifically, the developer could be allowed to resume on an interim basis if the following actions are taken:

- Procurement by PGV of an additional portable Jerome equivalent gas monitor for use by regulatory agencies
- Modifications (that will require parts that may be long lead time) to the fixed gas monitoring stations
- Tightening of quality assurance practices
- Increased regulatory presence on site
- The installation of additional abatement equipment by the developer

Longer term tasks relating to air and noise monitoring include:

- Relocation of some of the gas monitoring stations
- Installation of meteorological equipment at certain monitoring stations

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- Development of a database of geothermal fluids from each well
- The establishment of a unified air monitoring program panel consisting of the developer, regulators, environmental groups and residents, to advise on air and noise monitoring

The Task Force believes that these longer term actions are highly desirable and should be pursued, but are not critical for the resumption of development activity at the PGV site.

Almost all of the outstanding tasks will require the resources of the Department of Health, which has noted that unanticipated financial and personnel demands in responding to this incident have already drained their budget. Therefore, to get immediate relief and supplemental funding to comply with the action items, the Task Force urges that the Governor and Mayor direct their budget and financial staff to place the highest priority in assisting all Departments to obtain resources necessary to comply with the action plan.

STATUS OF SUSPENSION AND DECLARATION OF EMERGENCY

PGV voluntarily suspended drilling activity at their site as soon as the blowout occurred. The County Planning Director and the State Director of Health formally suspended drilling activity shortly thereafter. The suspensions, broadened by the County Planning Director to include non-drilling development work on the surface geothermal fluid gathering systems and the power plant, is still in effect. The suspension of all development activity was taken to ensure that the government's regulatory mandate to protect worker and public health and safety remained uncompromised. The only way to achieve this objective was to assure that any discrepancies or shortcomings in the developer and government equipment and procedures were corrected prior to resuming work.

On July 30, 1991 the Mayor proclaimed a State of Emergency at PGV's well site because there were subsurface symptoms, confirmed by the State and County investigators, that the KS-8 well was not fully under control. This proclamation allowed the cognizant agencies to expeditiously approve the drilling of a nearby water well by the developer for the purpose of quenching and finally killing the KS-8 well. Quenching was completed in early September, but the Mayor's proclamation remains in effect as of this date until there is certainty that the KS-8 downhole corrective measures taken are completely effective.

CONCLUSION

The Task Force believes that PGV can be allowed to resume non-drilling site development work (i.e. plant construction, steam collection system work, etc.) as soon as the well KS-8 is declared successfully secured. This determination must be made by Hawaii County Civil Defense with the counsel received from DLNR, DOH and the County Planning Department.

The Task Force believes that PGV can be allowed to resume drilling activity only after the following critical tasks are completed:

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- All recommendations related to drilling activity covered by the Element I report have been fulfilled.
- Adequate monitoring capability is in place.
- The Emergency Response Plan has been updated, revised and accepted.

issue.doc

JOHN WAIHEE
GOVERNOR OF HAWAII

WILLIAM W. PATY, CHAIRPERSON
BOARD OF LAND AND NATURAL RESOURCES

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STATE OF HAWAII
DEPARTMENT OF LAND AND NATURAL RESOURCES
P. O. BOX 621
HONOLULU, HAWAII 96809

REF:WRM-FC

JUN 24 1991

MEMORANDUM

TO: The Honorable John Waihee, Governor, State of Hawaii

FROM: William W. Paty

SUBJECT: Authority to Enter into Letters of Agreement for Element I of the proposed Geothermal Action Plan, an Independent, Technical Investigation of the Puna Geothermal Venture Unplanned Steam Release, June 12 and 13, 1991

Element I is the first of three elements of the proposed Geothermal Action Plan. Element I is described in detail in an accompanying memorandum.

This request is to provide for an independent, third-party, technical investigation to establish the cause or causes of the unplanned steam venting which occurred at Puna Geothermal Venture's plant site on June 12 and 13, 1991.

The investigation team will consist of the following four individuals: (1) Richard Thomas, Supervisor, Geothermal Unit, California Division of Oil and Gas; (2) Dick Whiting, Resource Engineer, Nevada Department of Minerals; (3) James Moore, Senior Vice President, Natural Resources, California Energy Company; and (4) Duey Milner, drilling consultant and former Drilling Supervisor, Nabors Loffland Drilling Company.

Separate letters of agreement will be entered into with these four individuals. The estimated contract term will be fourteen days. Travel to Hawaii is scheduled on Sunday, June 23, 1991. Services are to commence on Monday, June 24, 1991. Estimated billing rates for the two private-sector consultants is $500 per day. The services of the two public-sector regulators are expected to be provided by their respective agencies as a courtesy to the State of Hawaii. Round-trip airfare is estimated to average $1,000 per person. Per diem expenses of between $125 and $150 per person are being offered. An

JUN 24 1991

overall budget of $30,000 is proposed. Interisland travel, ground transportation, office space, and clerical support will be provided by the State at no cost to the investigators.

The scope-of-work set forth in the letters of agreement will call for the consultant to serve as a member of an investigative team which will: (1) establish the cause(s) of the incident; (2) evaluate the adequacy of PGV's drilling and blowout prevention equipment and procedures; and (3) make recommendations for any appropriate changes in equipment and/or procedures.

The letters of agreement will require that a written investigation report in draft form be submitted to the State on or before Wednesday, July 3, 1991. The report will consist of: (1) comments on reports obtained from PGV, its affiliates, and its contractors; (2) a presentation of conclusions drawn from direct site inspections and interviews with involved personnel; (3) findings as to the cause(s) of the incident and recommendations regarding measures needed to prevent a reoccurrence; and (4) an opinion on whether or not the well (KS-8) can be operated safely in the future.

The written report will be made public after the State determines that it is complete. The report will be used by DOH, DLNR, and the County as a basis for making decisions on any appropriate enforcement actions and on the continuation or lifting of the drilling suspension presently in effect.

Authority is hereby requested to enter into these agreements.

APPROVAL/DISAPPROVAL

____
JOHN WAIHEE
Governor of Hawaii

Dated:__________________

JOHN WAIHEE
GOVERNOR OF HAWAII

STATE OF HAWAII
DEPARTMENT OF LAND AND NATURAL RESOURCES
P. O. BOX 621
HONOLULU, HAWAII 96809

WILLIAM W. PATY, CHAIRPERSON
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STATE PARKS
WATER RESOURCE MANAGEMENT

REF:WRM:DK

JUN 25 1991

MEMORANDUM

TO: Honorable John Waihee, Governor
State of Hawaii

FROM: William Paty, Chairperson
Board of Land and Natural Resources

SUBJECT: Authority to Enter into a Contract for a Technical Review of the Puna Geothermal Venture Unplanned Steam Release of June 12 and 13, 1991.

This request is made on behalf of the directors of the Department of Business, Economic Development & Tourism, the Department of Health, and the Department of Land and Natural Resources.

The unplanned steam release, which began without warning at approximately 11 P.M. on the night of June 12, 1991, alarmed the nearest residents to the PGV plant. Residents of the Lanipuna Gardens subdivision were required by Civil Defense to evacuate their homes. Other residents from the Leilani Estates subdivision and nearby areas evacuated their homes voluntarily. Steam continued to vent for a period of 31 hours, emitting nuisance levels of hydrogen sulfide gas and noise and raising concerns about more serious adverse health effects.

The recommendation was earlier made to you, by memorandum from me dated June 16, 1991, that DLNR, DOH, and the County of Hawaii jointly administer an independent third-party review of the unplanned steam release. The basic scope-of-work of the proposed contract(s) will call for technical experts to: (1) determine the cause of the incident; (2) evaluate the adequacy of PGV's blowout prevention equipment and procedures; and (3) make recommendations for any appropriate changes in equipment, procedures, and/or government regulations. DLNR will serve as the lead agency, since it issues drilling permits and has enforcement powers in this area. In order to expedite its completion, the review will be handled administratively. We hope that it can be accomplished within approximately two weeks.

A special interdepartmental selection and review committee led by Mr. Susumu Ono is in the process of assembling a "team" of experts. Subject to the availability of qualified individuals on short notice, the plan is to engage on a short-term basis the technical services of four specialists including: (1) two public sector geothermal drilling regulators; (2) a drilling engineer or reservoir engineer; and (3) a drilling technician ("tool pusher") with considerable hands-on experience.

The selection and review committee is in the process of contacting the California Division of Oil and Gas, the Nevada Department of Minerals, and the Geothermal Resource Council in an effort to assemble a suitable team.

The independent third-party review will consist of the following elements: (1) an evaluation of PGV's written report on the incident; (2) and investigative report based on a site inspection, reviews of logs and records, and interviews; and (3) a written report finding the cause(s) of the incident and recommending measures needed to prevent a reoccurrence. The written report will be made public along with a joint agency report describing (any) regulatory, monitoring, enforcement, and/or punitive actions to be taken based on the findings of the independent experts.

The estimated cost of the required consulting services is $30,000, including consulting fees, airfare, and travel expenses. Contracts will be entered into with up to four individuals. If employees of state governments are selected, it may be necessary to enter into agreements with agencies such as the California Division of Oil and Gas or the Nevada Department of Minerals in order to obtain the services of their personnel. The duration of contracts entered into will not exceed one month. DOH, DLNR, and/or DBEDT funds will be used.

We hereby request your authorization to enter into these contracts.

APPROVED/DISAPPROVED:

JOHN WAIHEE
Governor of Hawaii

Date

STATE OF HAWAII
GEOTHERMAL ACTION PLAN

ELEMENT III, PART I

INDEPENDENT AIR AND NOISE PROGRAM REVIEW CONCERNING THE JUNE 1991 UNCONTROLLED VENTING OF THE PUNA GEOTHERMAL VENTURES KS-8 GEOTHERMAL WELL

SUBMITTED TO: Honorable Lorraine R. Inouye, Mayor
Hawaii County, State of Hawaii
and
Dr. John C. Lewin, M.D., Director of Health
Dr. Bruce S. Anderson, Ph.D., Deputy Director
Department of Health, State of Hawaii

PREPARED BY: ROBERT L. REYNOLDS, APCO & NCO
LAKE COUNTY AIR QUALITY MANAGEMENT DISTRICT
883 LAKEPORT BLVD.
LAKEPORT, CA 95453

DATE: JULY 22, 1991

-Acknowledgements -

The authors would like to thank the following people for their assistance and information in compiling this report. They showed tolerance, patience and good will, that made the work possible in the time frame imposed. The hospitality and continued interest shown by members of the Hawaii public to the LCAQMD staff over the years motivated the effort necessary to perform this work.

Honorable Lorraine R. Inouye
Mayor Hawaii County

Dr. Jack Lewin, M.D., Director
Bruce S. Anderson, Ph. D., Deputy Director, Environmental Health
Hawaii Department of Health
DOH Staff:
Dr. Sam Ruben M.D., Harold Matsumura, Wendell Sano, Clifford Furukado, Paul Aki, Kathy Hendrichs, Glenn Kawanishi, Jim Ikeda, Jerry Y. Haruno, Philip J. Wong, J. Mark Ingoglia, Lisa McPherson and several un-named.

Dean Nakano
Hawaii Department of Land & Natural Resources

Harry Kim, Chief
Hawaii County Civil Defense

Norman K. Hayashi, Director; and Rodney Nakano, Planner,
Planning Department, County of Hawaii

Public Members:
Rusty & Jenny Perry, Jane Hedtke, Janice Wilson, Mr. &Mrs. Olsen, Mr. Irvine, Greg & Debbie Pommerenk, Gary & Nancy Alexander,

PGV Staff and Contractors:
Zvi Reiss, Director Of Projects; William J. Templow, Field Manager; Donald "Don" Kiwimagi, Safety Supervisor; Terry L. Crowson, Drilling Superintendent; Tectonic Staff; Kim Bourne & Doug Cover, SAIC; and Tom Norris, Walsh, Norris & Associates

LCAQMD staff members: Special thanks to Ross Kauper, Deputy Air Pollution Control Officer; John Thompson, Air Quality Engineer; and Alex Dorn, AQA for report preperation.

Table of Contents

1.0 Executive Summary

Review by the Element III, third party team began on July 1, 1991 and consisted of Mr. Robert L. Reynolds and Dr. Wilson Goddard, assisted by LCAQMD[1] staff members Mr. Ross Kauper and Mr. John Thompson.

The scope of the project included: 1) a review of the air and noise monitoring program as implemented at the Puna Geothermal Venture project during the "KS-8 uncontrolled vent of June 12-14, 1991", with a special emphasis on making recommendations for extent, equipment, location, quality of data assurance and management changes; 2) a precursory appraisal of issued ATC[2] and GRP[3], complaint response and regulatory practices to assess compliance and effectiveness of control technologies given the new information; 3) suggestions on how to better anticipate, mitigate and manage possible future similar events from an air quality and noise perspective with the public input and technology considerations; and 4) to develop an accident scenario and emission profile independently for use in Part II of this report in which a micro meterological assessment, and determination of correlation with health and measured aerometric values is presented.

Emissions of noise and air pollutants caused widespread complaints and concerns. Some residents in the local area were evacuated as a safety precaution, advisories were issued and ambient measurements of noise and H2S indicated levels markedly above those anticipated in the issued permits as limits or believed to be acceptable. The emergency response plan interacted with the DOH[4] role in monitoring and making recommmendations for actions taken to manage the event.

There are seven air monitoring stations presently operated by three semi-independent parties. The three independent efforts of PGV[5], DOH•CAB[6] and DOH•ASAB[7] need to be combined into a single monitoring program directed by a committee of agency, industry and active environmentalists (see section 4).

---

[1]LCAQMD - Lake County Air Quality Management District, a California special District that enforces federal, state and local air and noise regulation with extensive geothermal.experience.

[2]ATC - Authority to Construct permit issued by the DOH pursuant to federal and state law for the protection of air quality.

[3]GRP - Geothermal Resource permit issued by the County of Hawaii for the protection of the public, and specifically in this case regulation of noise.

[4]DOH - Hawaii Department of Health

[5]PGV - Puna Geothermal Venture, the owner or permit holder. Used Interchangeably with Ormat Energy Systems International in this report.

[6]DOH•CAB - The Clean Air Branch of the Hawaii Department of Health

[7]DOH•ASAB - The Air Surveillance and Analysis Branch of the Hawaii Department of Health

Two background stations and other stations have provided data establishing a near zero background. The number of stations, seven is in excess to what should be necessary for compliance monitoring. The program should direct a greater amount of resources to other areas of the air program; most specifically, source testing and characterization of emissions, abatement technology application and compliance testing, and ambient monitoring for components other than hydrogen sulfide (H_2S[8]).

Several stations need to correct noted equipment, quality assurance and audit deficiencies, primarily DOH•CAB stations.

Though recommended changes in air monitoring stations are made, it is clear considerable data was provided by the air monitoring in place to establish exceeds of the 100 ppbv limit. Air monitoring stations with a couple of noted exceptions produced reasonably reliable and meaningful data. PGV's monitoring effort follows their issued ATC. The field monitoring effort by DOH and PGV was extensive and provided reasonable and believable data.

There was little or no mitigation proposed or sought during the uncontrolled venting to control air or noise emissions. This process lead to venting in a manner that increased impacts on local residential areas. Recommendations are made to have in place a wet cyclone or similar device for noise, H2S and particulate abatement.

There was no attempt to specifically estimate or measure net emissions of H2S and other components. This made management of the event cumbersome and the impact of unknown emissions difficult to estimate at the time of the accident or with hindsight. No drift or particulate samples were collected, though both are believed to have been emitted to the air in substantial amounts and a sample submitted by a public member raises concern. Insufficient information exists to accurately estimate emissions. It is recommended that testing become a normal part of management during venting, that DOH gain the ability to perform simpler teseting for H2S and that Condition 20 of the ATC be implemented promptly to measure trace toxic components. That such information to be gained by testing be used to trip toxic ambient monitoring requirements, review of potential plant reliability or corrosion problems, as well a review for potential abatement and improved management for any components of concern.

The ATC permits are extensive and criticized as regards: specific ambient air monitoring standard requirements which are too lax and not tied to an emissions

[8] H2S - hydogen sulfide gas the odorous and poisonous gas commonly referred to throughout this report.

rate, operate on a sliding breakdown or upset that is determined by PGV activities; allow natural (background) emissions effects that deviate significantly from EPA and typical air agency procedures to accommodate monitoring influenced by natural uncontrolled events; characterizing emissions timely; and are lax in requiring and substantiating BACT choices and claimed efficiencies.

The GRP required noise limits were exceeded by more than 25 dBA on a semi continuous basis during the event. The GRP required monitoring was reviewed for utility at determining compliance with limitations, and recommendations are made to clarify the permit and noise data measurement and reporting presently utilized.

Additional equipment for the purposes of emissions testing, inventory and ambient monitoring is recommended.

2.0 Recommendations

2.1 Air Monitoring Network

1. If background is consistently near zero, as indicated by this review, the use of background monitoring sites should be discontinued, and the cost savings for background monitoring should be redirected to source control, evaluation and high quality portable field monitors. The number of stations (7) exceeds that necessary for compliance determination.

2. Unify the air monitoring efforts into a single comprehensive program managed and audited by the state, but which receives and follows input and policy from a committee consisting of active environmentalists, industry and agency people. The existing DOH and contractor staff could share responsibility for the operation. The following attributes should be added:

• The monitoring program expanded to verify the concentrations of other potentially toxic pollutants indicated by reservoir and process chemistry. Examples include lead, chrome, mercury, boron, nickel, and arsenic.

• Each permanent H2S air monitoring station should have a meteorological measurement system and remote access (modem) capability incorporated. They should be password protected but access automated for those needing and using the information.

• A uniform functional, as short as possible, sampling intake, manifold, and monitor intake line should be used and cleaned regularly.

• Add a multi-sensor 30 to 40 meter meteorological tower to provide information relative to atmospheric stability, multi-level temperature gradients and wind fields, preferably at the Irvine site.

• A quality assurance program be implemented at all stations with independent DOH staff performing quarterly audits. The existing SAIC quality assurance program, or the GAMP program should be used as a basis to develop a single quality assurance program, but also correcting the noted deficiencies in reporting and audit approaches (see discussion sections).

• Two additional field portable H2S monitors (Jerome equivalent) be made available by the developer and properly maintained for use by DOH and/or other responding agency. One should be portable and configured for sample initiation by the public with automatic data recording. Local firemen and other agencies likely to respond to a hazardous H2S event should have one or more safety systems for use with each responding crew which give numerical readout and audio alarm.

• Recommended Actions at existing stations are summarized below and further discussed in section 6.

Recommendations Applicable (see below Key)

Station / Recommend Key->	1	2	3	4	5	6	7	8	9	10	11
Alvarez Station (CAB)	X	X	X	X	X	X	X		X		X
Wade Station (CAB)	X	X	X	X	X	X	X		X		X
Leilani Station(ASAB)			X	X	X		X	X	X	X	X
Nanawale Station (ASAB)			X	X	X		X	X	X	X	X
Ormat (PGV) SW				X		X	X		X		X
Ormat (PGV) SE				X		X	X	X	X		X
Woods Station (PGV)				X		X	X	X	X		X

Recommendations Key (not necessarily priority ordered):

1. Manifold, intake probe and sample line replacement or modification to remove condensation needed immediately.
2. Immediate and independent gas phase audit is needed (full probe preferred at all stations).
3. Improvement in written station procedures, data handling and station equipment diagram needed soon.
4. Manifold, intake probe and sample line regular cleaning.
5. Establish a station log and perhaps monitor log that remains with the station and equipment.
6. Offset chart zero by 10% and carefully document drift if accuracy in the 2-6 ppb range is to be claimed. Establish tolerances in the QA program that reflect the desired low concentration accuracy.
7. Add password level remote access integration into the QA and data reduction of station data. Provide password level controlled immediate access to agencies desiring and needing information.
8. Add meteorological measurement ability.
9. Calibrate and audit station at a lower range of H_2S than presently utilized.
10. Add functional data loggers (CAB is presently preferred)
11. Prepare monthly tables showing hourly averages and peak daily H_2S values, and DOH should clearly identify station location, name and operator.

3. Specific to the short term utilization of the present monitoring station resources; reference Map A shows a preliminary proposed station redistribution and possible reduction in number for discussion. It is recommended to occur only with a shifting of those resources to the control technology assessment and source testing effort, and can rationally be delayed until after power plant startup and shakedown if such is to occur in the immediate future. Only one station at a time should be relocated. If in fact the public or others are in disagreement, tracer releases under varied meteorologic conditions should be performed to identify locations and weather patterns of maximum impact prior to moving stations. Field portable monitoring could be used to partially substitute, and more thought as to the actual and expected emissions scenarios of the project need to be developed to influence this decision.

- Retain only (1) one background station at Nanawale (Flower Rd.) . Drop the PGV Woods Station.
- Relocate the PGV Southeast Station more to the southwest to avoid heavy agricultural influence and provide for increased community coverage.
- Relocate the Alvarez Station approximately 2000 ft. north or drop.
- Retain the Irvine Station for met data only and add multi-level measurement capability for wind and temperature.

2.2 Geothermal Resources Permit and Noise Monitoring

1. Clarification of the GRP requirements reflected in this review should be performed. One government office should be designated to receive and investigate complaints of noise. They should be available to any person that would choose to complain to them instead of PGV. Anonymous complaints should be taken, and investigated if practical.

2. At least one mobile/portable unmanned monitor with shelter and modem access, that can be used at complainant homes and is capable of determining compliance should be made available to Hawaii County or others.

3. Spot checks should be performed more frequently by an agency staff to add credibility. More frequent site inspections of PGV's effort and periodic comparison of calibrators could also add to the credibility and acceptance of the noise monitoring program.

4. The present noise standards should be evaluated for effectiveness by reviewing all complaints and their resolution. Typically, noise assessments for source and BACT determinations are specialized. The Planning Director should, if he believes it is necessary, seek expert opinion on BACT assessments from an

independent consultant paid for by PGV but contracted with and reporting to the County.

5. The monitoring effort should be directed to resolve complaints and identify source problem solutions.

6. There is too great an emphasis on monitoring sound and part of this effort is recommended to be directed at specific problem noise identification.

7. Determinations of BACT should be sensitive to the worker safety aspects, and not allow early choices of equipment to dictate subsequent noise control steps that unreasonably create a choice between a safety and noise problem.

2.3 Permit and Compliance Review Recommendations

1. The 100 ppbv one hour average limitation (AAQS) be evaluated from the experience of this incident and review. Evaluations of remaining health complaints should be performed by DOH as promptly as practical.

2. One government office be designated to receive and investigate noise and air quality complaints believed to result from the project. The present practice of recording tape messages, reading back and referring complaint directly to PGV should cease.

3. Resource characterizations required under Condition 20 of the ATC be performed as soon as practical and evaluated on a timely basis to better understand and estimate emissions, and determine if project design problems may result from any unexpected resource characteristic.

4. DOH staff should, actively participate in source tests, and develop the ability to independently quantify H2S emissions during drilling, stacking and uncontrolled or controlled venting. Specifically, the following is also recommended for timely consideration.

• Measurement characterization of drift and trace toxics contained in particulate and gas phase must be performed during emission release events until such time as they are well documented and established.

• An emphasis should be placed on developing an accurate and comprehensive emissions inventory and geothermal resource chemical constituent database specific to the project and individual wells.

• Emissions limits and/or technology development and application to all known emission points based upon Best Available Control Technology (BACT) should be further developed, and tested for performance under good dispersion conditions before needed (start with the stacking control system).

• The possible need and advisability of air drilling should be investigated and the restriction removed from the ATC permit if necessary to provide safety in drilling.
• The need to factually determine whether a pressure surge (gas pressured) from the bottom of the hole in the reservoir, or water/mud hammer, caused the "explosions" is critical to potential risk, and DOH staff should seek an expert final opinion explained to their satisfaction.
• The maximum accidental exposure to those in close residency should be re-evaluated, and where concern exists, the individual resident be educated as to risks, made aware of any bad circumstances or risky operations as early as possible, and given whatever assurance possible about DOH resolve to protect their air quality.

3.0 INTRODUCTION

Element III is the third element of the Geothermal Action Plan by the State of Hawaii to investigate the unplanned venting incident on June 12 and 13, 1991 at the geothermal plant site of Puna Geothermal Venture (PVG) in Kapoha, Puna District, Island of Hawaii, involving the KS-8, a geothermal well. The lead agencies for this review are the State of Hawaii Department of Health (DOH), the Hawaii County Planning Department and the Mayor's office.

This Element III study was conducted at the request of the above agencies by an independent investigative team consisting of Robert L. Reynolds, Lake County Air Quality Management District, and Dr. Wilson B. Goddard, Goddard and Goddard Engineering, both of California. Work was initiated on 7/1/91, with the primary emphasis being an independent evaluation of the existing air and noise monitoring programs, monitoring the incident, and to develop recommendations for the appropriate changes in the monitoring program equipment and procedures. Secondary tasks included an evaluation of permits. Part II authored by Dr. Goddard includes a microscale meteorological evaluation of the project area and accident meteorology and an assessment of health complaints compiled with public member assistance. The accident can serve as a learning experience from which an improvement of the overall regulatory program can result. The investigators were assisted by Ross Kauper and John Thompson of the LCAQMD, whom performed review of data for consistency and aided in evaluating recommendations for station relocation.

3.1 Approach

The investigative approach was to collect and review the available documentation regarding monitoring station operation and the emissions event information. The team exchanged data and initial findings approximately every two days since July 9, 1991. Mr. Reynolds traveled to Hawaii and conducted meetings and interviews with DOH and County of Hawaii officials on July 1&2, 1991. Site inspection and meetings with public representatives in Hawaii were conducted on July 2, 3 & 4, 1991. Videotaping and phone interviews were performed to obtain additional understanding of actual operations and insight regarding measured area impacts. Meetings and conversations with the state health agencies, interested public and developer representatives occurred to refine the scope of the investigation and obtain additional insight regarding related aspects of the event.

The available information was gathered and analyzed for completeness and additional data requests and follow up were performed, not all are yet complete. Information analysis included evaluation of visual features, observations of site visits and video tape recordings of all equipment. Monitoring and quality assurance data was reviewed for completeness and internally checked for obvious errors or conflicts.

The event sequence and provided mud logs were reviewed for possible information regarding timing and source strength from which assumptions regarding emissions estimates were derived for use in impact assessment. This was performed without input from Element I.

Steam and or gas composition data was collected and reviewed to provide information regarding other possible monitoring concerns.

Included in the data requests were adequate area, monitoring and complaint location maps, that were plotted by Dr. Goddard, for the correlation of observed measurements and reported effects (See Part II). Also included were requested and reviewed copies of the ATC permit.

Information was largely reviewed as received, but substantial additional questions were asked of industry and vendors. When timely received, it has been incorporated into this report. Several questions remain. Individuals knowledgeable in geothermal development, services and regulation were relied upon and interviewed to obtain added insight in regard to specific questions to their area of expertise. Part I of this report is a compilation of the authors understanding and experience with the subject area and represent his best judgment. Part II of this report is authored by Dr. Goddard.

3.2 Approach Health Survey and Dispersion

-See Part II

4.0 Existing Aerometric Monitoring Program

4.1 Existing Aerometric Monitoring Stations

At the time of the site visit seven H_2S air monitoring stations were operational. The Hawaii Department of Health (DOH) operates four of the stations. Each of two stations report to two different Deputy Directors. The Clean Air Branch (CAB) is part of Environmental Health and the Air Surveillance and Analysis Branch (ASAB) is part of Health Resources. The developer, OESI or Puna Geothermal Venture (PGV) utilizes a contractor "Science Applications International Corporation" (SAIC) to operate three additional stations. These stations are listed below with an indication of the H_2S monitor type, presence of meteorological and noise monitoring instruments and operating entity. Considerable additional documentation on configuration is available but is not included in this report. Each station's location is shown on the attached Map A.

Station Summary

Name	Location	Type	H2S	Met	SO2
Alvarez Station (CAB)	Kaupili Street	C	X	X	X
Wade Station (CAB)	Leilani Avenue	C	X	X	X
Leilani Station(ASAB)	Kahukai Street	C	X		
Nanawale Station (ASAB)	Flower Road	B	X		
Ormat (PGV) SW	Adjacent to HGP-A Site	F,P	X	X	
Ormat (PGV) SE	1800 ft. SE of Well KS-8	F,P	X		
Woods Station (PGV)	NE of Project Kapaho Rd.	B	X		
Irvine (SAIC)	Kahukai Street	C			
Mobile (CAB)	Between KS-8 and E Pad	P			

Key: C = Community, B = Background, F = Fenceline, P = Permit
PGV = Puna Geothermal Venture, ASAB =Air Surveillance and Analysis Branch,
SAIC = Science Applications International Corporation,
and CAB = Clean Air Branch

<u>4.2 Site Visits</u>

Each of the air monitoring sites were visited and videotaped for reference on July 2&3, 1991, and the equipment and records maintained on site were briefly reviewed. Quality assurance and quality audit data was requested prior to site inspection and again during the site visit if it had not yet been provided. The sampling lines/manifolds, water traps, calibration and Quality Assurance (QA) equipment were inspected for obvious leaks, bad connections, and maintenance practices. The station operators were interviewed to determine their extent of knowledge regarding the station equipment and manner in which it was utilized and serviced to demonstrate a reasonable level of understanding. The frequency of maintenance activities, span checks, precision checks and quality audits were discussed with station operators. An opportunity to explain any equipment problems that existed was provided. The manner in which collected data was handled was discussed and the appropriate data and station check forms were requested. Where available, the information was utilized in this review. Information available from the station logs, forms or note books including calibrations, span checks, and audits were reviewed.

4.3 Observations, Discussion and Problems

All existing stations produce reasonably reliable data, with the possible exception of: 1) the CAB stations when they experience water deposition and condensation problems in the sample acquisition system; and 2) the PGV-SE station being artificially low if H2S is scrubbed by material in the manifold. The operators appeared intelligent, familiar with the instruments, and capable of calibrating and maintaining the stations operative. Unfortunately, there is a need for an improved quality assurance and audit program, and some additional equipment and training at the DOH operated stations.

Quality assurance and auditing problems are minimal for SAIC, greater for ASAB stations and serious for the CAB stations. Quality assurance audits have not been performed at the CAB sites. The SAIC program could be used as a model for the other stations operational procedure, if desired. A quality assurance program requirement as developed and utilized in the Geysers is also provided in Reference 1 for consideration. The ATC permit required EPA guidelines do not exist for H2S monitoring but may be successfully adapted from existing EPA SO_2 monitoring procedures. Attention must be paid to some of the parameters if a 1-3 ppbv sensitivity is sought.

At a minimum, the SAIC and both state programs should be audited semi-annually by independent DOH personnel and equipment and preferably on a quarterly basis. ASAB staff would appear to be in the best position and qualified to accomplish this task. Audits should be performed by using equipment independent from that used for station calibration and precision checks, otherwise true independent audit requirements are missing. If possible, it would be most desirable to audit from the intake probe on at least an annual basis. DOH personnel should inspect SAIC stations on a regular basis and consider being the primary contract manager of SAIC instead of PGV, though PGV would pay costs of the contract.

Three different operational entities, operating three small monitoring programs of similar purpose is difficult to endorse. All could benefit from a sharing of resources to improve spare parts availability, audit frequency, staff time and operator resource without an increase in costs. Additionally, it was noted that the DOH stations operate without the extreme security measures that were implemented with the SAIC sites (cyclone fences and razor wire). DOH stations were in easily accessible areas and apparently better accepted by the public.

The two separate state programs and PGV's sponsored SAIC program should be modified to carefully complement each other, and preferably combined into one effort governed by a committee that includes significant public environmental representation and influence in decisions.

There is a need to assure the public that the monitoring results are valid and that the stations are there at a considerable cost to serve the purpose of protecting the public interest. It may be appropriate to form a consortium under the auspices of the state to perform the monitoring program and specifically identify the stations to indicate their public importance. Removing the razor wire from the PGV funded stations would reduce the negative public perception of the monitoring program function. It should be emphasized that monitoring station operations are one of the most visible manifestations of commitment to the protection of public concerns.

Each participant should play a role that enhances the other in performing the monitoring, quality assurance, quality audits and data verification which adds credibility even with recalcitrant detractors. The data should thus be credible and reported as accurately measured numbers which is made widely available. Problems with past efforts to monitor should be acknowledged, since it is likely some skepticism results from a failure of that system to report events that some public members clearly believe they experienced on a semi-continuous basis during the HGPA project.

Similar circumstances were experienced in the Geysers Geothermal Area development prior to the formation of a consortium Geysers Air Monitoring Program (GAMP). This program includes active environmentalists and industry and air regulatory agencies who share the decision making power for the Geysers Air Monitoring Program (GAMP). This unification of mutual interest provided for public input, helped establish the program objectives and reviewed and unified all available monitoring data. The purpose of the effort was to generate technical aerometric information everyone would accept. We are presently in the third renewal of the program. The costs are paid by the industry and a contractor operates the stations. The method of operations were determined and are audited by air agency staff. New industrial members have joined and the program can be adjusted to accommodate any new monitoring needs. This model would seem appropriate for the Pahoa area. At a minimum, DOH should audit the SAIC operated stations on a regular unannounced basis, and possibly serve the role of contract administrator by having PGV pay costs through the state whom would contract with SAIC. This would increase the credibility of the data in the public's view and assist PGV/SAIC in establishing credibility of the air monitoring program that is well deserved.

4.4 Access to Data and Modernization

Modem access to the SAIC stations is possible at present, but apparently is not utilized by DOH. It was not used during this event. To add this feature to the CAB stations would require minimal effort. The ASAB stations reportedly have new data loggers planned and could incorporate modem access. This attribute of data availability should be incorporated promptly into the information tools available to DOH, both for operational and QA functions, and to assist in emergency or other air management decisions.

The ASAB stations were in the apparent process of equipment changes and the CAB stations were only recently established in February of this year. The H2S monitors (not sampling) system equipment at all sites can be considered modern and near state of the art. The data logging and permeation tube calibration equipment at the ASAB stations is outdated and in need of replacement. Permeation tubes are more problematic than gas bottle dilution systems. All stations had proper shelters and temperature controls. The data loggers were nonfunctional at the ASAB stations, but plans are reported to exist for the upgrade of this equipment. Each entity performing ambient monitoring utilizes a different sample line and manifold system.

4.5 Intake Manifold and Sampling Line Problems

There is a serious problem of water condensation within the sample acquisition system and a potential for significant analyzer interference at the DOH•CAB stations. This appears to result primarily from the stainless steel heated intake probe and manifold not performing in the desired manner. Condensation was so severe in the sampling line at the "Wade Station" as to cause water pooling in the sample line prior to the sampling line particulate filter. A potentially more serious sample line problem exists because of observed corrosion on the exterior of the stainless steel probes. Similar corrosion is presumed to be occurring in the internal surfaces of the probe which may scrub or oxidize H2S and therefore reduce instrument response. The extreme amount of condensation observed in the sample system will also affect the operation of the SO2 scrubber, and potentially cause H2S to be scrubbed. A verbal recommendation to promptly first audit all DOH stations and rectify the condensation problem at CAB stations was given during the site visit. The ambient sample is drawn from the heat traced manifold horizontally which may also contribute to the condensation problem. These factors could be expected to cause ambient H2S readings to be reported considerably lower than are actually occurring. Attempts to dry and purge the line were immediately made, but the condensation problem was again present the next day.

The SAIC and ASAB stations use a combination of Pyrex and Teflon for manifold and sample line. The probes and water drop or insect traps are set up in a typical manner to ensure a short residence time and maximize the removal of dirt or water droplets. The sample line is withdrawn vertically from the top of the manifold. They appear to perform well with no condensation noted but may retain a considerable number of trapped insects. In all observed sites more frequent cleaning of the sampling manifold appears to be necessary. This is especially a problem at the SAIC - Southeast Station where spider webs and a light (oil) film was observed in the manifold. The station operator explained that the agricultural location of the station was an especially serious problem for spray exposure(s). The general degraded state of intake probes/manifolds cleanliness needs to be corrected by regular maintenance at all stations, and can be suspect of causing artificially low level H2S values. This is especially important since no audit or check has ever been performed using the entire probe/sample system, and that also measures the contamination effect which may reduce the H2S levels prior to analysis. A weekly check, and cleaning, if necessary, would seem appropriate, and maybe relocation if the problem is not controllable. It is advised that the external intake probes be directed downward (even though positioned under an inverted funnel). Consideration of a coarse insect screen to reduce insects entering the sample manifold might also be appropriate, but should be further investigated and tested before implementing. The SAIC stations use a large diameter intake pointed upward and are therefore especially susceptible to the insect and agricultural spray problems.

Consideration should be given to using a uniform sample probe configuration that can be as short as possible, incorporates an effective water droplet and insect trap, having inlets directed downward, and which avoids the water carryover/condensation problem. The assembly should be easily leak checked and cleaned, or replaced on a regular basis at all sites. The manifold should be positioned or balanced to best track ambient temperatures in an attempt to avoid condensation.

4.6 Quality Assurance and Data Reduction

Written quality assurance procedures, with appropriate work sheets and forms are customarily utilized at air monitoring stations. CAB stations in particular were remiss in this regard, with only a notebook (which is taken off site) used to record QA activities and instrument adjustments. Only the SAIC stations had posted procedures, adequate work sheets and the customary bound station log. The station log allows a proper record of station problems, activities and status that is not removed from the site (duplicate sheets are created). The ASAB stations, as a result of the initiative of the operator, had a draft operating procedure for the TECO instruments, diagrams and clear procedures.

ASAB stations are audited by a semi-independent party quarterly. Unfortunately, the ASAB equipment utilized is not totally independent, and is typically used to check the permeation tubes at both ASAB operated stations. Data loggers were not functional at ASAB stations. The technician that performs the audits also services the station and as such, a proper independent audit does not result. The Irvine station had apparent slow response problem(s) and required two hours for the daily span and zero check. This response is indicative of equipment problems which should be resolved. The ASAB stations are considered the poorest equipped because of the use of permeation tubes, absence of data loggers and meteorological monitoring.

Data reduction procedures at the ASAB stations were largely by hand reading of the strip chart, and by data logger dump to a personal computer at the CAB stations. Monthly data tabulations could not be provided. In both cases the results had historically been that only zeros were measured and therefore the formal data reporting had been placed on a low priority.

SAIC has an extensive QA and data handling program that is well documented and formalized. Still SAIC data tabs show a 1 ppb at 01:00 hours frequently, which is likely an artifact of the automated span check. These types of instruments are actually only accurate to plus or minus 2 ppb, or maybe worse, for zero baseline measurement reporting. Data should be corrected as presently reported. The stated zero drift tolerance of .025 ppm in the quality assurance plan fortunately is not used, but again provides good reason to utilize a 10% chart zero offset to determine the extent of the zero drift.

4.7 Background Data Stations

A review of available measured H2S background data has apparently shown little or no existing H2S in the vicinity of the project. Actually, all sites show zero H2S except when attributed to a source event, or as in the case of SAIC data a suspected artifact of the span check. Background station operation is at considerable expense and the continuing effort is difficult to rationalize as necessary, as incorporated into the ATC permits in the present manner. A natural emissions inventory could be carried out in the general area, and if sources are not identified that are likely to contribute, a years worth of no detectable amounts of H2S for background should be considered acceptable as establishing background as near and indiscernible from zero. Additional meteorological monitoring is likely to be more helpful in discerning any influence of VOG or future volcanic activity, should it occur, and procedure worked out by the EPA and California Air Resources Board for such events could and probably should be followed.

It is suggested to use zero H2S as the background value and simplify the enforceability of permits. The resource saved could be redirected to provide better meteorological monitoring, remote data access, source testing and other pollutant monitoring that would address public concerns.

4.8 Strip Charts or Hard Copy of Data

Strip charts can be invaluable for use in an area that experiences power failures or when instrument problems begin to happen. Strip chart recordings were offset by 10% only at the ASAB stations; however, data loggers at the other sites can report negative numbers as well as over range numbers and are useful in determining instrument operation. Nevertheless, it is suggested that dual trace charts be utilized that operate in two ranges such as 0-100 ppbv and 0- 500 ppbv, and that a 10% zero offset be utilized to better track and document instrument drift for the operator. A ten inch chart is also markedly easier to use when attempting to read in the 5 ppb range. The span and zero drift limits are tolerable, given the apparent measurement objectives, but need to be clearly delineated (especially SAIC's QA) as to when adjustments are to be made. All operators appeared to be aware of this problem.

4.9 Meteorological Monitoring at Stations

There were only three met stations operating as part of the system at the time of the site inspections. These were located on 10 meter towers at the CAB Wade & Alvarez and SAIC-SW stations. QA procedures were adequate at SAIC, but were not documented at CAB. The method of alignment at SAIC was customary and easily confirmed from the ground. CAB needs to adopt the procedure of aligning the vane and monitoring arm with true north to easily verify direction by site inspection and independently audit at least once after establishing a station. The Irvine site, with its elevated geographical location, is suitable for additional meteorological monitoring and should include such immediately if concern over additional venting exists.

5.0 Existing Noise Monitoring Program

5.1 Monitoring Program Description

An extensive effort is put forward to monitor noise by SAIC under contract to PGV. A PGV staff person charged with permit(s) compliance on site has also begun to play a more active role in the noise complaint handling and monitoring effort.

The extent of noise monitors exceeds permit (GRP #21) requirements for monitoring but may not be recording and utilizing the necessary data. PGV has three permanent and one mobile continuous noise monitoring stations, one hand held unit used by PGV staff for complaint evaluation and one that is reportedly loaned to the public. The Hawaii County and DOH each have a hand held B&K monitor which is apparently utilized intermittently. All PGV equipment is modern Quest Model 2700 or 2800, B&K, etc., yet it is not clear that the necessary L_{10} can be measured while under automated operation.

An open ended pipe microphone housing is utilized and intended to be somewhat directional (pointed at the project area). The housing also provides protection from the elements; however, they can also be expected to exaggerate the effect of the rain, wind and insects if they enter or fall on the steel chamber. The microphones are 1/2 inch Type I, but do not incorporate a dehumidifier. The calibrators are certified by the manufacturer on the recommended schedule.

Hourly averages are logged and included with aerometric data at the SE and SW sites. They are downloaded daily and reviewed by SAIC in San Diego. Additional data loggers are maintained with the stationary monitors and downloaded into a personal computer for further reduction. A five inch strip chart recorder is maintained of output data. An SAIC descriptor is available providing more detail on equipment and procedure. The data at the SE and SW sites is remotely accessible. The stations are summarized in the table below.

Noise Monitoring Resources

Name	Location	Make	Model Number	L_{10}	L_{Max}
Leilani Station (Irvine)	Kahukai Street	Quest	2800	M	M
Ormat SW, F	Adjacent to HGP-A Site	Quest	2700	?	?
Ormat SE, F	1800 ft. SE of Well KS-8	Quest	2800	M	M
Mobile (PGV), P	Between KS-8 and E Pad	Quest	2800	M	M
DOH	Hand Held	B&K	2231	X	X
County of Hawaii	Hand Held	B&K	2225	X	X
PGV	Hand Held	Quest	2800	M	M
PGV	Hand Held - Public Use	Quest	2800	M	M

Note: L_{10} and L_{Max} are not available commonly on all instruments.

5.2 Geothermal Resource Permit (GRP) Requirements

From a simple reading of Condition #24 of the GRP, the following is offered as the applicable two components of the GRP noise limit. The first limit is an L_{10} of 55 dBA day and an L_{10} of 45 dBA night (slow A scale) for 20 minute reporting intervals. The second limit is a 65 dBA day and 55 dBA night maximum (slow A scale). Authorized exceptions, and procedures for defining them are given in part C. Monitoring is not presently configured to determine compliance with these limits. Monitoring is not presently performed at the nearest residence, and it should be made clear that the SW and SE sites are acceptable alternatives to the nearest residence requirements for enforcement. A L_{10} value for 20 minutes would customarily require more than minute samples to determine.

It is obvious that part "a" intends to apply a limit that is modified by part "b" and the time interval set for this modification is 20 minutes. It might also be argued that from the reading of part "b" that unless the noise is impact in nature then limits of "a" apply. It is also clear that BACT is required for exceptions provided in part "c", and would be determined on an individual exception basis. It was not possible to evaluate if BACT is being applied for exceptions.

The actual noise limit applicable as practiced and adequacy of reporting is not clear to this investigator. Does the 10% time allowance of a 10 dBA increase apply to an L_{10} measurement for 20 minute intervals or a maximum of two, one minute intervals out of a concurrent running 20 minute period of time? Can you exceed the general limit by more than plus 10 dBA?

It would appear from PGV's present practices that they compute the hourly averages at monitoring sites, and determine if they exceed the limit. They also compute and report the twelve hour averages, but it is not clear why. If they do exceed they see if three or more one minute plus periods of the 20 minute intervals were also exceeded. If not, then an exceed doesn't occur. If an exceed occurs, they then determine what caused it with the assistance of the near source monitor. If it isn't the project (i.e. crickets, rain, etc.), then the incident is not acted upon. The slow dBA maximums and a determination whether they go over the 65 and 55 dBA levels are apparently not reported.

5.3 Regulatory Noise Needs

DOH or Hawaii County should have at least one monitor with shelter and modem access that can be used at a persons home when there appears to be a conflict with the developer. Sound activated tape recorders can also be very useful in some circumstances. Spot checks performed by an agency would add credibility. Site inspections of PGV's effort and periodic comparison of calibrators could also add to the credibility and acceptance of PGV's noise program.

The present noise standards are not likely to be completely acceptable to the community as levels are allowed to exceed those required for sleep and quiet outdoor activity. Open windows are apparently customary in Hawaii and worsen this situation. As the complaint response requirements are intimidating and may not be appropriate for a friendly resolution of the noise complaint(s), especially if in compliance and impossible to mitigate, it may place PGV in a difficult circumstance to resolve. The standards might even be construed as deceitful given the obvious fact that the wording allows a level 10 dBA higher 10% of the time than the 55 and 45 dBA stated as a general noise limitation.

Typically, noise assessments for BACT are not easy. The LCAQMD has completed a study and finalized a report that has been made available to Hawaii agencies. This might serve as a start. If necessary, the Planning Director should seek advise from an independent consultant. This is one area where an ounce of prevention (especially prior to constructing) is worth a ton of control after the fact.

As an example, steamline pressure release valves were observed during the site inspection to be without mufflers and not directed away from residents. They should be muffled and possibly directed to an abatement system to be considered to qualify as BACT. They are designed to respond to emergencies and will sound like a large explosion when ruptured because of an over pressure. This would appear even more important if wellhead shut-in valving must be manually operated to correct this condition.

As a general comment, except for the requirement of BACT, the GRP and monitoring program fails to acknowledge that dBA's determine the level of sound, not noise. Some sounds are extremely irritating, such as brake squeal, and even at low dBA levels mitigation should be applied. While this fact will be essential to incorporate into any successful program, it is not achieved without substantial and careful evaluation of complaints genuinely and sincerely given. Clearly a preventive technology based and not reactive complaint based regulatory program is preferred.

Footnote: People don't complain about noise until they are already angry!

6.0 Uncontrolled Venting of KS-8

6.1 Accident Scenario

The accident or uncontrolled release scenario involves several phases, and while these are not certain, assumptions must be made if the dispersion and ambient measurements are to be evaluated with meaningful hindsight. The Element III Team was to be provided the Element I report but as of 7/17/91 had not received the report. The following is therefore offered as a plausible sequence of events as reconstructed from reports and interviews. Video was provided by the public, but video considered confidential was not viewed nor was evidence taken that should be treated as confidential. The confidence in the scenario is thus lessened and may warrant correction.

The initial release of gas and H_2S occurred on 6/12/91,18:49 hrs.; while circulating the bottoms up (drilled material settled on the bottom) after a long period of stationary inactivity. The drilling mud apparently released H_2S as a distinct and sharply defined value on the mud measurement equipment (186 ppmv peak). Carbon dioxide emissions also increased and were likely mixed with the H2S. This gas release plume was probably cool, contained heavy gases and would be anticipated to be poorly or non buoyant, and may have been transported intact in light winds. There were several odor complaints from neighbors shortly after, which were probably caused by this release; however, it is unlikely that this release contributed to the high ambient H2S measurements observed later that night. After the initial momentary release, the mud showed only normal levels of CO2, and no H2S release is apparent until the major uncontrolled venting incident.

The more serious incident began at approximately 23:16 hrs. and involved two or possibly three quick initial releases of gases and/or steam that caused considerable damage to the drilling equipment and shook windows of nearby residence. The shock waves have generally been described as explosive and may have been the result of water or mud "hammers" built up in the well bore as gases or vapors evolved. The fluids gained velocity as they were driven to the surface, and compressed the vapor as they encounter a mechanical blockage. They are a common problem dealt with in handling high temperature geothermal fluids.

It is uncertain as to the exact nature of the initial release, but it would appear that a large fracture was encountered capable of producing high temperature flashed steam. Entrance to a void area may account for the observed weight on the drilling hook significantly increasing, and within the next few minutes a recorded 14 foot drop of the Kelly. Drilling mud temperatures and pumping pressures increased then significantly dropped. The gas/vapor release or explosion necessitated the temporary abandonment of the rig. This initial phase, including the described "explosions", are assumed to have contributed little in the way of significant H2S emissions, since the rig deck personnel were reported to have not been acutely exposed to H2S or steam burns. It is not clear any personnel or occupational exposure alarms were activated. The alarms may have been deactivated by the explosion, but even that is not certain. The mud monitoring equipment was believed to have been made nonfunctional after the first "explosion".

This initial "explosive" phase was followed by a continuous release of a plume of saturated steam and water which passed through various points of the rig floor, through the rig structure siding, out the dog house windows and any open or ruptured line communicating with the well bore. The plume rise was estimated at approximately 65 feet. Portions of the plume were redirected downward as it exited the rig deck skirting. The estimated steam flow was 150,000-200,000 lbs/hr. The H2S concentration was not measured, but judging from KS-3 and other nearby well test for flashed steam, 700-900 ppmw is considered a good approximation. Given the concentration and estimated flow rate, an emissions rate of 105 to 180 pounds an hour of H_2S results. PGV estimated 30% of the water content remained in the flashed steam and reported observing a characteristic popping noise likely resulting in evaporative cooling. The release continued without apparent change until approximately 06:00 hrs on 6/13/91.

At approximately 06:00 hrs on 6/13/91 a line relieving pressure from the casing was opened, directing the steam horizontally to the west northwest in a 254° direction with considerable momentum towards the residential areas. The internal diameter of the choke line is 3" (assumed double strength 4" pipe). The choke release height is 66" above pad level. Emissions continued as described previously, though assumed at a reduced rate from the choke or "HCR" line providing a pressure relief. The total well steam emissions are presumed to have increased given the two separate release points with the majority of emissions exiting the choke line. Assuming an approximate 35 foot, 4" double strong pipe (3.1" ID), and a 3" gate valve fully open, the flows were estimated at 370,000 lbs/hr with 1500 PSI well head pressure 119,000 lbs/hr, at 500 PSI. Since flashing and carry over occurred, the flow utilized is 200,000 lbs/hr, though obviously variable. The total steam release is estimated to have increased to 200-250,000 lbs/hr following the inclusion of the choke line. The plume from the choke line was reported to have mixed to the ground as it passed over the pond and under the canopy of nearby papaya trees.

Water was pumped down the drill string reaching the bottom of the hole beginning at 10:30 hrs. on 6/13/91. Venting continued until 04:00 hrs. on 6/14/91 at which time the choke line was closed and water was pumped down the annulus (well casing minus drill string) causing a pressure drop from a reported 1,700 to 900 psi, and significantly reducing emissions. LCM (plugging material) was introduced to the annulus and successfully plugged the escaping steam from around the steel rams and emissions from the well were reported as controlled by 10:00 hrs on 6/14/91. Most emissions ceased as evident from the noise data by 0600-0700 hrs on 6/14/91. Odor complaints continued and were confirmed by DOH•CAB staff. PGV is uncertain as to the occasional small steam releases continuing, or the possibility of a gas cap forming and slowly leaking as gas of possibly high concentration. The last verified odor complaint apparently occurred at 22:15 hrs. on 6/15/91, and can perhaps be explained in Part II of this report as return flow. If not, one must assume emissions from from KS-8 occurred and caused the complaint.

6.2 Field Air Sampling and Noise Monitoring During the Event.

The electrochemical cell alarms and Houston Atlas H_2S analyzer on the drilling site apparently were rendered nonfunctional by the accident and apparently did not sound an alarm. Instantaneous or short term measurements were made by a number of different individuals and compiled by PGV and DOH staff for consideration. They are incorporated by reference and constitute a substantial information base.

The H2S monitoring equipment used included a Color Tech Rotating Head Sampler (DOH), Gas-Tech and Draegar Tubes (DOH & PGV), and a Jerome (PGV) field portable hand held monitor. Of these methods the Jerome 631x, followed by the Draegar and Gas Tech tube methods are most reliable. A degree of darkening determination must be made for the Color Tech's Rotorods after a specified interval of rotation and are judged more difficult to accomplish, especially at night. DOH should plan to convert to a Jerome or similar equipment.

A considerable number of measurements were made in the immediate area by DOH staff. These numbers validate the fact that the stationary air monitoring instruments were not necessarily measuring a worse case at any given time. Unfortunately, the high value measurements recorded on the property and off the project that initiated the evacuation, were not compiled as part of those data sheets.

Questioning of PGV and drilling staff disclosed that several values in the ppmv range were measured. The first values reported, consistent with the Emergency Plan requirement, were directly downwind of the uncontrolled vent off the project site and were the highest reported at 29 & 22 ppmv (29,000 & 22,000 ppbv). These values, reported by a PGV staff member, either resulted in, or confirmed the early decision to evacuate the Lanipuna Estates. Questions were posed as to whether the value was in error, and if it could have possibly been a misread of the display. The PGV staff member who made the measurements stated the second reading was to make sure he had not misread the instrument, and that he had not misplaced the decimal. He appeared to be competent, knowledgeable and capable of properly operating the instrument. He had previously used the instrument. Generally three distinct samples are taken, but the first sample should, if not representative, be lower than the actual number.

On 6/14/91 the instrument was compared to an H2S excursion measured at the Irvine Air Monitoring Station and agreed within 10%. At the time of the site inspection on 7/3/91 it was suggested that a span check be performed, but the instrument had apparently suffered a malfunction, and was to be returned to the manufacturer. No reason to disqualify or discard the numbers generated by the instrument are apparent.

The PGV staff member deserves compliment for acting in a responsible and timely manner consistent with the Emergency Plan in reporting the values. The middle of a potential emergency is the wrong time to doubt an instrument purchased for and used in the manner designated. Subsequent numbers taken by Draeger and Gas Tech methods make the initial high numbers even more plausible. A reading of 20 ppmv was reported adjacent but immediately upwind of the rig, a 5 ppmv value was reported approximately 500 ft downwind measured at 10 am on 6/13/91, and a 2.9 ppmv value was reported as measured at 600 feet downwind at about 11 am on 6/13/91. All occurred after the 29 ppmv measurement taken immediately after the accident. This information would indicate a validity of the higher number based on the lesser dispersion likely to have occurred with the initial release under nighttime conditions.

The use of this Jerome 631x owned by PGV was extensive. From conversations with PGV and DOH staff, and in our experience, it is more likely to produce useful, timely, extensive and accurate data than the other methods utilized. The survey mode is especially appropriate for use in cases of accident investigation to warn the user as well as make measurements. The H2S values collected by the Draegar or Gas-Tech method, can be considered reliable if in the ppm range. They are more characteristically used in the work environment. The Color Tech Rotorod is not advised simply because superior alternatives exist. The sample is an integrated 10 minute or longer sampling and the degree of shading must be judged from a comparison chart subject to operator interpretation.

6.3 Field Noise Monitoring During the Event

The noise monitoring effort was significant and continued throughout the event. There is little disagreement that the legal limits were exceeded by a substantial and continuing amount at all permanent monitoring stations. The reader is referred to the "Puna Geothermal Venture, Noise Monitoring Program, Well Blow Out Data Report, June 1991". The uncontrolled venting noise levels clearly exceeded GRP permit limits by 25 to 35 dBA. Numerous spot measurements were made by a consultant and PGV staff whom surveyed the area and reported similar results demonstrating the widespread noise exceeds. Compliance was re-established after controlling the vent.

6.4 Drift and Emissions Estimates

Results of an analyses of drift reported to be deposited on the windshield of a visitor to the site using EPA method 601 was submitted by a public member and is presented below. Catchment analyses was performed on four homes. Apparently, these are the only samples taken during the event for constituents other than H2S. It should be noted that such sample collection, while of interest, does not establish the deposition rate which is critical to understanding any effects. It may, however, establish the need to consider decontamination cleaning of equipment with significant drift deposits and indicate a need for additional source and ambient testing. Sample collection three weeks later is not viewed as rational, and such was not suggested. The components of the windshield deposit is as follows:

Component	Reported value	Units
Lead	678	ppmw
Nickel	90	ppmw
Chromium	72	ppmw
Manganese	118	ppmw
copper	16.3	ppmw
Zinc	19.2	ppmw
Arsenic	less than	10 ppmw
Iron	6.53	percent
Aluminum	1.56	percent

The catchment samples were taken on the afternoon of 6/13/91 and show no exceeds of drinking water standards, though some components of concern were shown to be present at the Alvarez residence. The data should be compared to future, or if available past, analysis. If the effort was properly designed, and consideration of water volumes, rain, evaporation, etc., were incorporated, these sites might serve as long term recording sites. At the present time it is inappropriate to conclude anything other than the catchment waters met suggested standards on 6/13/91.

6.5 Monitoring And Actions That Should Have Been Considered

No abatement was in place and no apparent or reported attempt to barrier the noise, sample the plume, or redirect the plume was made. Plans for the future should bring these issues forward for consideration promptly once personnel safety issues are addressed. A system should be prepared and valved into place during any future high risk drilling to control noise and air emissions. A cyclone and H2S abatement system as used during air drilling might be appropriate.

There was apparently no drift samples collected by DOH or PGV. This task could have been easily accomplished at established intervals downwind, and would have aided greatly in assessing the potential impact on water catchments and particulate release. No sample of downwind TPSP or PM-10 measurements were made.

The permits require quantification and characterizations of emissions by the permit holder after a malfunction resulting in a 100 ppb exceed. These are apparently not available (see ATC Condition #23) and as of 7/15/91 they have not been provided and are assumed to not exist. The closest located characterized well is KS-3. Test data from it and other nearby wells were obtained from Thermochem which is contracted to PGV for chemical analyses. These analysis are utilized to produce the emissions plume descriptors. There is no assurances that the characteristics of KS-7 or KS-8 is similar, and in fact given the reported 30 ppmv values for H2S on the rig deck during the KS-7 "gas kick", they may be significantly different. The evaluation of drift deposited on the windshield from the plume of KS-8 would indicate such is the case.

6.6 Emissions Estimates of Trace Components

The following concentrations were utilized as estimators for potential impacts and are based largely on well KS-3 and KS-1A simply because that was the only data provided for close proximity wells. Additional data may be available but has not been provided. A steam condensate analysis for well KS-3 was performed by Utah Research Institute on 3/30/91 and provided on 7/15/91. Sampling methods did not detail if a complete steam analysis was accomplished but a verbal check and review of the results indicate a simple analysis of condensate. Ion closure was not apparent. Values were reported as non detectable except for salt components. It appears that the analysis required by ATC Condition #20 have not been completed and significant portions of constituents largely ignored from an analytical chemistry perspective. The possibility of using HGP-A data was suggested, but judged inappropriate as the resource is somewhat removed. The issue of brine occlusion and drift carry through in the absence of flashed steam passing through a separator is difficult to ascertain (it is estimated a 30% carry through occurred). The constituent contaminants entering the flashed steam depends significantly on the dynamics of the flash and water droplet removal process, especially if down hole flashing is occurring. A conservative approach would be to use the brine numbers directly, or at 30% although emissions level estimates would be biased high.

Component	Lower	Upper	Units
hydrogen sulfide	493	1200	ppmw
ammonia	0.168	1.49	ppmw
arsenic	unreported	unreported	
lead	unreported	unreported	
cadmium	unreported	unreported	
chlorides	unreported	unreported	
boron	unreported	unreported	
mercury	unreported	unreported	
ph	unreported	unreported	
Total Dissolved Solids	unreported	unreported	
Total Suspended Solids	unreported	unreported	
nickel (not required)	unreported	unreported	
chrome (not required)	unreported	unreported	
	unreported	unreported	

The only data that appeared relevant and could possibly be used to determine components of flashed steam were for KS-1A total brine and post flash brine. Mass balancing using the reported 0.7989 flash fraction is shown below. The data does not appear to be useful since the computed values are likely within the analysis error.

Component	Post Flash	Total Brine	Steam, ppmw
Arsenic	0.49	0.1	0.00182876
Mercury	0.0017	0.0003	-5.241E-05
Boron	8.43	1.7	0.00591689
Silica	1170	235.27	-0.0212793
Aluminum	<2.50	<.50	na
Barium	32.3	6.5	0.00559519
Manganese	8.13	1.63	-0.0061873
Chloride	18500	3720.06	-0.3629991
Fluoride	0.91	0.18	-0.0037564
Sulfate	14.2	2.86	0.00548254
Total Dissolved Solids	33100	6655.89	-0.650895

After some dicussion and analysis, it was determined a valid characterization could not be provided, but is dependent upon the nature of volatilization and carry through. Therefore in Part II of this report emissions are assumed to be 100% of those of brine provided in the ATC application.

The reader is refered to Part II of this report for an estimation of brine content based upon the PGV application provided information, and estimates of possible impact.

6.7 Event Evaluation & Recommendations: an Air Quality Perspective

The accident was not anticipated nor acknowledged until underway. Abatement technology to control emissions was not in place. Management and analytical characterization of emissions was not available. This limited the assessment of impact potential. Field measurements were not correlated to emissions or the configuration characteristics of the release as the accident continued. Estimation of emissions did not occur though venting continued for a substantial period of time. The accident happened during a least desirable time of the day to handle an emergency.

In forecasting and detecting the event, it is apparent the failure of down hole temperature probes, the earlier gas release of H2S resulting in complaints, and the lost circulation should help warn operators of risk in the future. It may be practical to improve the mud logging gas detector(s) response time by adding a second but less sensitive detector or Jerome type sensor with a quicker response time to the mud monitoring operation. Presently, the configuration and instrument have a delay of several minutes. Relocating the mud sampling device (versus sample transport through a sample line) is an alternative. A second readout device could also be displayed on the rig deck. Drilling slower and circulating more mud when near suspect depth, paying attention to bottoms-up characteristic and carefully monitoring the heat load and volume changes of the mud (this is done at present) are obviously appropriate, given hindsight. The issue would be how slow to drill, and to take steps that maximize the response speed. It may be appropriate to look for mud components (i.e. high chloride) characteristic of geothermal brines, or other gases that might be occluded into the mud and not necessarily be released or detected. If a high pressure entry appears likely, appropriate parties should be notified and placed on alert and continued drilling delayed to reasonable daylight hours.

If an accident or pressure release occurs, it would be desirable to be prepared to characterize the emissions as soon as practical. The on site Ex-Log (Tectonic) staff are generally capable of doing this for H2S and should be assigned the task with possible assistance of other staff. A direct in-steam sample probe might be necessary and should be prepared ahead of time. Samples should also be collected for other components such as drift and particulate. Analysis should be repeated as frequently as practical and necessary to track the venting steam characteristics. An estimate of emissions release point height and total release would be necessary, and could be made from visual inspection, well head pressure (if necessary it can be estimated from the temperature using steam tables) and the size of vent(s). This information should be provided to the emergency or event managers whom can with this information and existing real time meteorological data, utilize mathematical models to anticipate the worse case plume path and probable concentrations. Field staff can be directed to these areas to establish the validity of predictions through monitoring and to visually observe downwind locations and areas generating public complaint.

Air pollution control technology to treat an uncontrolled or forced-release should be required to be in place and operational prior to drilling in areas at depths suspect of behaving like KS-8. This could include valved in large capacity pressure relieve valves, H2S abatement capability, wet cyclones for particulate removal and noise mitigation, and possibly even a large capacity muffler or stack. A typical system is shown in Figure 2, which also utilizes hydrogen peroxide to oxidize and stabilize H2S. These need to have the capability of being promptly or automatically activated. The system should have an overcapacity, be directed in the best direction and sampling ports built in at appropriate locations to allow determination of emissions. Consideration of removing the ATC limitation on air drilling should also be evaluated if the developer believes that method to be safer, and perhaps more capable of controlled drilling. The practice of allowing short term uncontrolled venting (7 minutes, per ATC) needs to be evaluated as to possibility of appropriate concern for loosing control of such venting and rather abatement is in place to mitigate.

During the site inspection, a review of the records and interviews with staff, the quantifying and considering of the above factors was always a secondary objective. This is really the only way to protect the public. No amount of monitoring, after the fact analysis, or good intention will improve the air quality without the preventive steps to avoid, control as necessary and manage temporary emissions.

6.8 Interaction with Emergency Response

PGV staff and agency staff did act responsibly in implementing the Emergency Response Plan, which is the subject of Element II. PGV and their staff member whom acted promptly and reported the first high values displayed a commitment to the protection of the public. This was apparent from the joint committee on Element II meeting attended.

It is clear that you can not put enough permanent air monitoring stations in the community or deploy sufficient field monitoring equipment to measure pollutants at the time of a large air emissions release to represent "worse case" which will tell you, with certainty under all possible conditions, when to evacuate without the considerable risk of being too late, in error, or without an adequate safety margin. It is for this reason that emergency responders also need to consider personal H2S safety alarm needs.

Monitors such as the Jerome, which can measure over a wide range and also act as a personal warning system (in survey mode), are best suited for field measurements in suspected high and low value areas. The use of mathematical models as noted above, can be automated with modern meteorological systems, but this type of system must be in place prior to any accident. If an accident and event continues for an extended period of time, as the subject one did, such tools can prove invaluable. The compliance and community air monitoring system can greatly assist in making and confirming decisions and impacts, but only if emissions data is also available or they happen to be in the worse case location.

When developing a new resource and technology there simply are no guarantees, and to offer such is to raise skepticism in a careful person. A good healthy dose of such skepticism for DOH staff would be appropriate for this project at this point. The drilling safety, blow out prevention and well integrity issues should properly be the responsibility of agencies which specialize in the area, or a third party (with adequate bonding and insurance) should be utilized to assess developer procedures and plans.

7.0 DOH Authority to Construct Permit No. A-833

It was agreed prior to the initiation of this independent investigative effort that a permit review could not be accomplished in more than a precursory manner, and would need substantial more time than available at present to complete. The summary below is mostly relevant only to the specific uncontrolled venting accident of 6/12/91/ to 6/14/91 and should not be considered complete or relevant to the many required performance criteria, plans, notifications, etc. The site was visited on the afternoon of 7/2/91 with DOH staff and again on 7/4/91.

The most relevant permit conditions are as follows. Condition #23 was implemented when the stations measured H2S above 100 ppbv for an hour average. Similarly if the uncontrolled venting is considered a blowout, Condition #26 applies regardless of impact. Both conditions require a report within five days that is to include "the estimated project emissions". Condition #13 has a similar requirement for well equipment failure. Condition #17 has a similar requirement for "each steam release incident" or "inadvertent release". To date this estimate has not been provided the investigative team, and was not available for the emergency planning. The level of contamination and net emissions from the source would have greatly assisted the emergency response, and should have been available in a competent manner as soon as possible. Emission estimates were also requested by this investigation for the KS-7 gas kick, but have not been provided. This lack of apparent source testing and emissions characterization makes it difficult to manage and greatly lessens the ability to learn from such accidents. The limitations placed on the emissions sources must ensure the ambient goals under worst case. Figure 1 utilized to explain the LCAQMD program explains in a simplistic manner the necessary components of a regulatory system. The permit at several points is confused by differing ambient goals under different operational or breakdown scenarios (i.e., the standard of performance is 5 ppb, a 25 ppb increment, or 100 ppb). There is an obvious attempt to make the permit BACT driven, but goals appear to be set to accommodate potential problems the developer may encounter, and not to achieve defined ambient air goals.

Per Condition #23 the drilling is to proceed only "after the permittee has demonstrated to the Department of Health that contributions from the well ... will not result in or contribute to the exceed hydrogen sulfide ambient concentration of 100 ppbv". This latter requirement is a substantial obligation and one that is unlikely to be made with great certainty. Clearly it calls for mitigation to control or avoid repeats of the subject uncontrolled venting. Condition #23 goes on to state notifications can not constitute a defense to violations.

Condition #13 requires "During well equipment failure or malfunction which result in hydrogen sulfide emissions, the permittee shall apply best available control technology, etc. It is not clear that the well equipment for Condition #13 purposes, also means during drilling. The electrochemical cell referenced for flow testing results were not available and it is not clear it has been or is practical to be utilized. If in fact they were available and deemed accurate, they should have been used to help quantify the uncontrolled venting emissions. The LCAQMD experiences with such devices has been negative in nature, and would warn that such results may be unreliable.

Condition #17 has several other requirements such as increasing the weight of mud, shutting in the well, limiting emissions to five (5.0) pounds per hour, no more than seven (7) minutes of venting, and "In no case shall air drilling be used". The 5 lb/hr emissions rate needs to be clarified as to whether it is an instantaneous rate or the two combined allow a "42 lb/hr instantaneous rate" or greater provided it does not continue for more than 7 minutes. The air drilling restriction may be counterproductive in the event the resource is different than expected. The removal of this restriction should be considered. Though it makes for more expense and difficult management, it may be the safest manner in which to proceed.

Condition #5 requires an ambient monitoring program that has been implemented, and is the focus of this report.

Condition #20 requires the very kind of information needed for power plant and well field environmental design considerations and to help estimate emissions as was desired in this case. Unfortunately, there is no specified time to perform or submit the data from the tests, and tests apparently have not been performed to date. The condition should be modified to be accomplished during initial well venting (clean out with no separator) and again during separation and flash testing. Given the high chloride content in the resource, tests should include gas phase HCL and possibly HF. Other constituents of concern should be considered as information develops on the character of the resource. Tests should be carefully thought out and performed using geothermal resource sampling techniques and analysis (not wastewater). Chemical characterization of the resource is critical at the earliest possible time to assist in ensuring that plant and emissions control equipment reliability is not going to be adversely effected by any unexpected constituent(s), and that unexpected emissions of concern not go unquantified. A very high temperature versus low temperature flash resource should initiate such careful review.

DOH staff should review circumstances and decisions as information is made available to assist in anticipating problems and in determining appropriate permit to operate conditions. Frequent and or long term stacking, if necessary because of reliability problems, will create air quality and project cost problems. The claimed BACT efficiency of the present stacking control for H2S and particulate removal (including injected NaOH) needs to be substantiated prior to need, by testing under good dispersion. It is likely the sunken location will present some unique plume characteristics. The effects of allowing direct infiltration of alkaline scrub solution laden with dissolved H2S needs to be evaluated. Especially given the fact that acidification of the waste stream will release H2S and such might be confused with background or geogenic H2S in the future. It appears that little need for the facility is anticipated, but only experience will determine this need and a careful update is appropriate.

The peak values of H2S are commonly five times the hourly average during the uncontrolled venting. People smell and commonly respond to peak or short term values. The closer the proximity the greater the maximum exposures are likely to be, and the worse the already intolerable AAQS of 100 ppbv will be considered by those exposed. This issue is especially relevant to Condition #17. More careful consideration in light of the complaints received should be given to lowering this limit, determining what technology to mitigate is available and possibly establishing a shorter term standard.

The number of reports and notices required per well is quite large and may serve to further enlighten as to compliance. They are listed below for further reference and should be evaluated as to whether they have been filed and contain useful information. It was beyond the scope of this effort to accomplish such a task.

Special Condition 2
- notification prior to construction

Special Condition 5
- siting plan for required air quality and met station(s)

- in the event of a one hour average H2S concentration greater than 25 ppb (above background) and 100 ppb (including background) Hilo Dist. Health Office also notified
- monthly air quality and met summaries
- annual electronic file (2 copies) for air quality and met data

Condition 7
- 2 days prior to aerated mud drilling
- 2 days prior to aerated water drilling
- 2 days prior to well venting
- 2 days prior to flow testing operations, and
- 2 days after completion of aerated mud drilling
- 2 days after completion of aerated water drilling
- 2 days after completion of well venting
- 2 days after completion of flow testing operations

Special Condition 9
- request to flare excess gas
- post event flaring report

Special Condition 13
- notification if abated H2S rate is 5 lbs/hr or more (flow testing)
- notification (immediate) of equipment malfunction/failure
- post event report within 5 days

Condition 15
- Daily reports on H2S upstream, NaOH injection rates, and H2S concentration and emission rates downstream during flow testing

Special Condition 17
- in the event of inadvertent steam releases during well drilling of more than 7 min/hr or H2S emissions of 5 lbs/hr or more

Condition 18
- chemical abatement plan prior to flow testing

Condition 19
- upon release of any toxic emissions into the ambient air (as mitigation)

Special Condition 21
- diesel usage (by engine and well) at completion of well
- certification of fuel injection timing adjustment (retard) for three diesel engines used for rig no. 2, prior to startup

Special Condition 22
- 2 day written in advance of unabated well venting
- Public notification (newspaper notice) 24 hrs in advance
- Residents within 3500 ft. notified 24 hrs in advance

Special Condition 23
- upon exceeding 100 ppb (one hour average) H2S ambient level
- post event report within 5 days

Condition 26
- upon well blowout
- post event report within 5 days
- weekly report - if a continued blowout

Special Condition 28
- H_2S hourly average for monitoring data >25 ppb (above background)
  Hilo Dist. Health Office also notified

Attachment I-7
- upon completion of construction or installation of any equipment covered by the A/C

Normal operations for implementation of the 5 ppb increment needs to be defined with certainty. Does this include stacking emissions should the plant have long term operational problems? As presently worded, it may encourage venting just to keep the limitation from being enforceable.

Review of the plant and well field components reliability in view of any significant changes in resource temperature, chemical characteristic, etc., and the likelihood that reliability will be affected should be carried out.

Drift and trace materials are measured in Lake County even now that they are largely controlled and very low, just to alleviate public concern and verify emission assumptions and measurements. Such a program should be considered for inclusion in Hawaii. Drift needs to be characterized for accidental and controlled vents. This includes clean outs, and future stacking relative to possible effects on catchments and vegetation. This monitoring would compliment the existing H_2S program and might also utilize PIXE or Dicot/XRF analysis of repairable particulate.

Meaningful source tests need to be performed and comparative results established for BACT decisions as published for stacking mufflers, and other components. These appear to be inconsistent with LCAQMD experience and the anticipated abatement needs to be tested as soon as practical by properly conducting source tests. The gas reinjection system is nearly identical to that used at Coso Hot Springs, which did not operate as hoped, and is now on a variance allowing two hundred and fifty (250) pounds per hour emissions.

8.0 Public Members, Comments and Questions Offered

The most common statement was that this (the accident) must not happen again. Clearly the public feels threatened by the event and the potential for reoccurrence. The belief that they have been ignored was common near the project area, and across the board all felt that the health effects issue was being ignored. Conversations with DOH and the Pahoa Homeowners association members lead to the recognized need to investigate and correlate complaints with technical dispersion information. This is addressed in Part II of this report. An attempt has been initiated that should be carried on. The data is unique and can add much to our knowledge about air pollution and H2S exposure.

It was also noted that reported effects sometimes given in response to a complaint and even the effects table for H2S indicates a less severe effect and mortal danger at higher levels than is more commonly accepted. For example, compare the PGV application with the DOH news release of 6/13/91. A fireman compared the numbers with a nationally distributed database, and asked if some people were more sensitive and what the effects were on infants. Obviously, these are real concerns that are only worsened when information conflicts. In reality, it is clear no one should be exposed to levels even approaching the higher levels generally quoted, and the fact that they will not be needs to be made completely believable.

The following questions and comments were also commonly expressed. How would this matter have faired if it had been on the E or HGPA pad sites? How close is too close. At times it is simply easier to just buy property or replace systems than mitigate against expected accidents! Nuisance easement or purchase of homes should be a possibility! Why aren't other toxic components measured? The state is just doing what the developer proposes in writing permits! It is obvious that public questions and emotions still need to be addressed.

Working on a common need can help turn the public into a resource instead of an adversary, by including them in reacting in a positive manner to an adverse situation. The need for community involvement, assurance and empowerment will be greater than ever if they are to accept the project as a neighbor. Obvious concern exists over future development, and if this could be better quantified it might lessen anxiety. The people are a real resource and their energy and concern must be directed to positive change.

Emergency Plan: The stationary air monitoring network can and should be used to assist emergency management decision making, but not as the primary criteria in the absence of reasonable worse case/location information.

Some people are convinced that there is a master plan and they have no possibility of influencing decisions unless they act irrational.

Conclusions Air

1. The plume release characteristics and quantity of H2S were more severe than assumed plausible in the existing worst case blowout scenario incorporated

into the facility permitting. Impacts were worsened by the nature of the uncontrolled release and the directing of the high velocity release plume through a pipe and valve setup in a horizontal direction toward the nearby residential area. Monitoring of noise and air was extensive.

2. A high of 29,000 ppbv (29 ppmv) was measured off the development property and reported. Additional measurements on the drill pad and approximately 500-600 ft downwind of the plume confirm the likelihood of this high value which initiated evacuation. Ambient stations recorded several excursions above the 100 ppbv level. Some air monitoring stations did not completely respond to H2S excursions.

3. A variety of methods were used to take measurements by several different parties. Not all of this data appears to have been compiled to date into one report. The higher values were not included in the data provided by DOH.

4. The existing stationary air monitoring network in place at the time of the accident was extensive for H2S. A total of seven (7) Pulse Fluorescence Detector (TECO and Monitor Lab) instruments were operational for the detection of H2S within a few miles (see map A). Only three meteorological monitoring stations were in place. A meteorological monitoring station established by PGV's predecessor was operated adjacent to the drill site until 6/12/91. However, the data was not audited or reported. This is really quite a wealth of exposure effects and monitoring information for air agency review. The health survey information provided by the public needs to be evaluated extensively, and the permit standards considered.

5. Minor maintenance and quality assurance problems exist at all of the air monitoring stations. These problems are more severe for DOH operated stations. With the exception of sample line condensation problems at the DOH•CAB stations, it is unlikely that the reported values are markedly different or lower than actual ambient H2S levels that occurred. The SE station manifold is dirty enough and has an oil film that could reduce reported values. The need for zero stability and calibration for H2S at low concentrations is great for the desired accuracy referenced in ATC permits.

6. No measurements of ambient drift, trace metal particulate, total particulate or gases other than H2S have been made by DOH or PGV.

7. No source tests to characterize the incident vented steam content of H2S, salts, particulate or trace toxics were made.

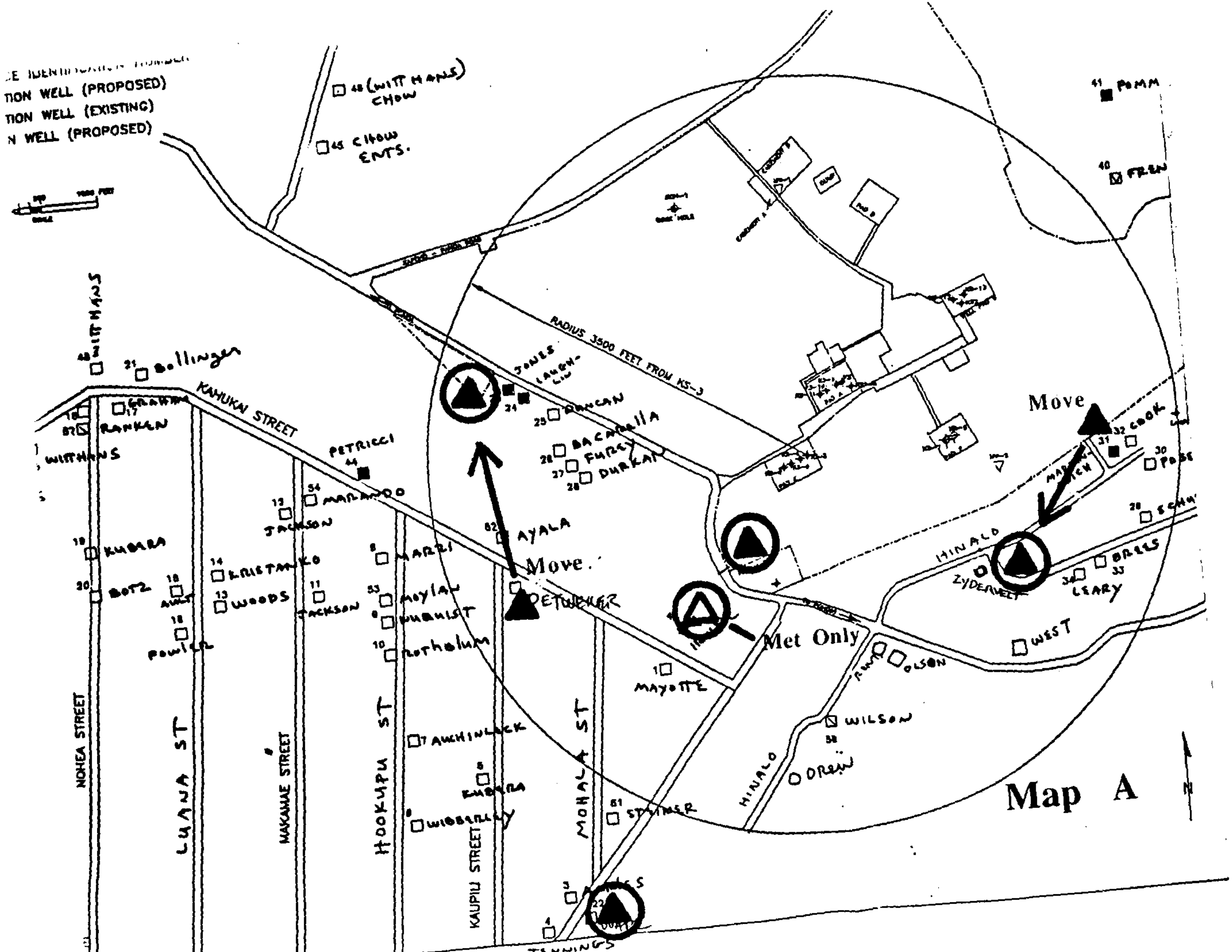
8. No attempt to abate air emissions or mitigate noise were made during the uncontrolled venting, other than to regain control and stop the venting. A high pH mud and water was reported to be used when trying to control the well that adds some abatement potential.

9. Health and nuisance complaints were made at a variety of locations to several agencies/parties. These have not yet been compiled into one report or the validity of the complaints completely investigated.

10. Resource characterizations required by the ATC permit for tested wells do not appear to have been completed to date or the data could not be provided this investigative team. The actual level and quantity of H2S and other emissions can only be estimated.
11. No quality audits of the SAIC stations by DOH have been performed or are planned. SAIC is under contract to PGV/OEIS not DOH.
12. No formal sharing of quality assurance or audit functions by the three entities performing air monitoring occurs.
13. A distrust exists between the various effected parties and government. The term at "war" was used. All parties need to get together to facilitate good management when an undesirable circumstance occurs. No one wanted, or should be willing to accept this accident as a continuing type of occurance, or desire to avoid remedying. This circumstance, in this investigators opinion, is a result of a lack or perceived lack of any major role played by DOH in resolving complaints, ensuring abatement and performing verification of permit compliance. The perception is not equitable to DOH and needs to be corrected. The permits also are in need of improvement. PGV operates and responds to most complaints in a process that would generally be considered somewhat intimidating. In short, some of the public doubt DOH is looking after their best interest when issuing or enforcing permits, and are concerned about bad politics, the unknown and additional perceived problems at the facility. The uncontrolled venting has heightened this concern and anxiety.
14. Any distrust of the public and policy makers will increase as the public learns the one hour 100 ppbv limit is unacceptable and that their complaints have commonly resulted at levels far below the value.
15. The close proximity of many residents heightens the potential for a high exposure occurring and going unmeasured. It is unlikely a warning can be provided for a massive and sudden release unless they are incorporated into the drilling program warning system directly.
16. Peak levels of H2S were commonly four to eight fold that of hourly averages measured (reported on clock hours).
17. Telephone modem access exist at SAIC operated stations, but is not utilized by DOH. Modem access to DOH stations is not in place, but could reasonably be added. DOH stations should use the CAB data logger with modem.
18. Source tests and characterization need to be completed promptly, including for such items as HCL and other corrosive materials.
19. The cellars are dangerous to the workers, and could add difficulty to any repair necessary. The need for them for volcanic lava flows should be carefully considered against risks. Someone is going to get hurt if an H2S head gas leaks through a valve, or they are in the cellar when an unintentional steam release occurs.

Conclusions Noise

1. During the uncontrolled venting, noise levels clearly exceeded GRP permit limits by 25 to 35 dBA. Numerous spot measurements were made by a consultant and demonstrated the widespread noise exceeds. Similarly PGV staff surveyed the area and reported similar results. Compliance was quickly re-established after controlling the vent.
2. PGV has three permanent and one mobile continuous noise monitoring station, one hand held unit used by PGV staff for complaint evaluation and one that is reportedly loaned to the public. The equipment is modern (Quest Model 2700 or 2800), and reasonably deployable to determine compliance with the GRP condition #21. The single ended open pipe microphone housing utilized is intended to be somewhat directional and provide protection from the elements; however, it can also be expected to exaggerate the effect of the rain, wind, and insects if they enter or fall on the steel chamber. It also excludes to some degree non project noise.
3. The limit incorporated into the GRP is cumbersome and could even be considered misleading. The levels allowed at night are known to interfere with sleep and daytime levels can interfere with speech. The permit condition uses uncustomary verbiage, and it would be difficult to establish compliance or violations with presently reported data.
4. The project noise is often the dominant noise in the area, though rain, wind, insects, and residential neighborhood noises dominate and/or contribute significantly to the noise levels measured at times.
5. Considerable SAIC/PGV staff effort is expended on the noise monitoring program, which is designed to isolate project contribution at times of complaints or exceeds. A complaint line and protocol of operation exists that would be intimidating to anyone whom is not an aggressive person or pushed to the point of being angry. It appears SAIC/PGV procedures do not measure L_{10}'s as required by the permit, and if automated measurement of such is not possible with the Quests monitors needs to be resolved.
6. DOH and Hawaii County has available a hand held B&K, but their involvement in evaluations of compliance or responding to complaints appears to be inconsistent. DOH's involvement is limited since the state ordinance applies only on the island of Oahu. Hawaii County responds to the complaints as required in the issued GRP.
7. Hand held monitors are unlikely to be able to easily determine compliance or a lack of such unless the maximums are exceeded, or part A of GRP Condition #24 is applicable in the absence of impact noises.
8. The direct drive drilling rigs are not normally considered BACT in Lake County, however the extent of noise mitigation is impressive to the point of perhaps qualifying as BACT. Unfortunately, the extent the rig must be enclosed to achieve noise goals must be evaluated from a drilling staff safety perspective.



TION WELL (PROPOSED)
TION WELL (EXISTING)
N WELL (PROPOSED)
RADIUS 3500 FEET FROM KS-3
KAHUKAI STREET
NOHEA STREET
LUANA ST
MAKAMAE STREET
HOOKUPU ST
KAUPILI STREET
MOHALA ST
HINALO
Move
Move
Met Only
Bollinger
WITTHANS
PETRICCI
MARANDO
JACKSON
KUBARA
KRISTANKO
WOODS
BOTZ
FOWLER
MARZI
MOYLAN
ROTHOLUM
AYALA
MAYOTTE
AUCHINLACK
WIBBERLY
WILSON
OLSON
WEST
LEARY
ZYDERVELT
COOK
CHOW

Map A

FIGURE 1

FUNCTIONS OF AN AIR QUALITY MANAGEMENT DISTRICT

The Lake County Air Quality Management District and other air districts in the state are charged with maintaining an effective air pollution control program to protect public health and welfare and thus ensure the enjoyment of the physical environment in which we live. Such a program must incorporate a method to attain and maintain air quality standards, abate public nuisance and health hazards present in the ambient air, and be responsive to nuisance complaints from citizenry. Minimum ambient air quality standards are set by the federal and state governments, and implementation plans have been enacted in all districts (generally consisting of rules and regulations) to attain and maintain air quality within these standards.

For even the most simplistic air quality control program there are several essential components. These include:

1. Establish a goal (ambient air quality standard);
2. Monitoring of the air (decide if the goal has been reached);
3. Determine the source of air pollutants (emission inventory);
4. Develop a control strategy (adopt rules and regulations);
5. Enforce control strategy (ensure compliance with adopted rules and regulations).

These activities are not independant of each other but are links in a chain; when one is nonexistant an effective control program will not exist. The ambient air quality standard is the most crucial parameter and determines the need for the other components. These components are presented graphically below.

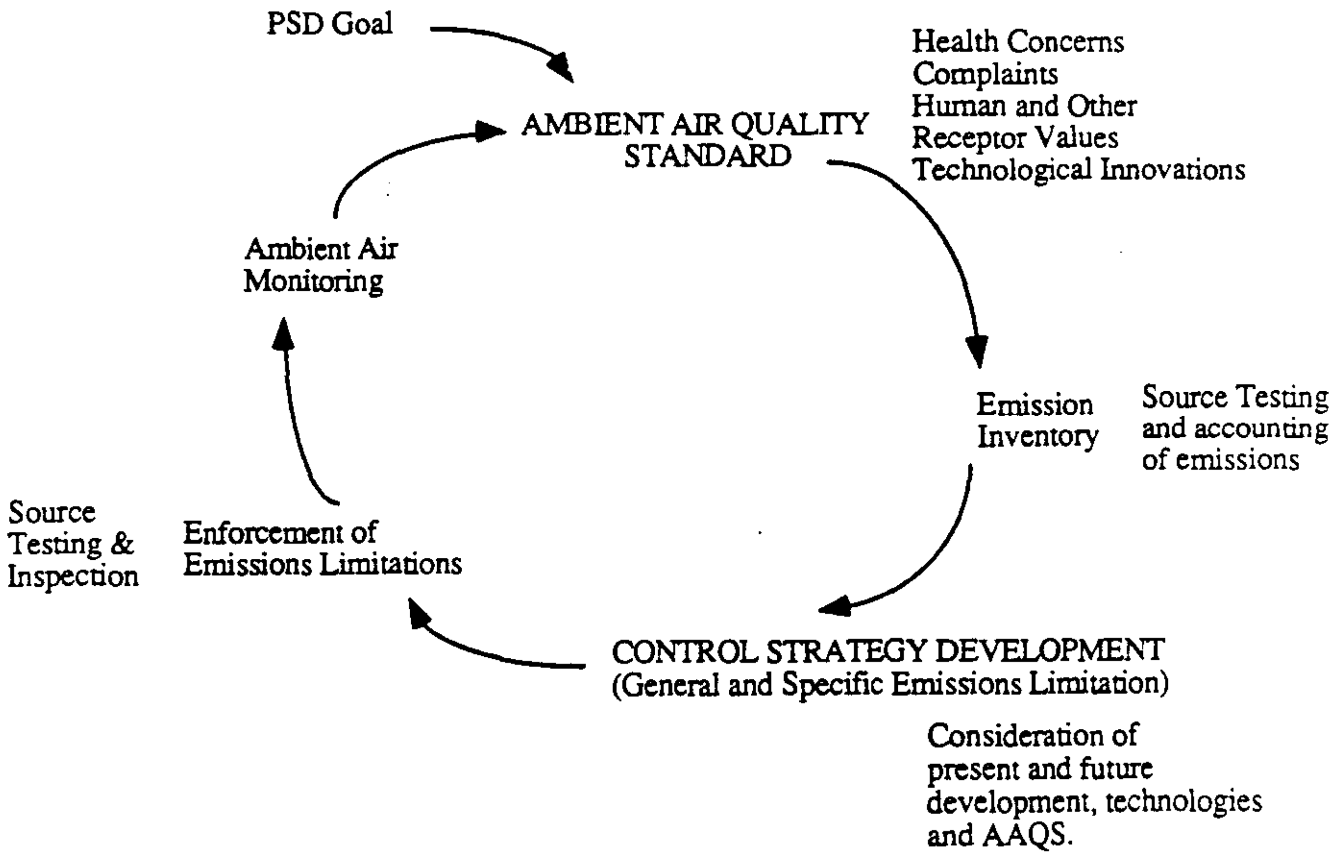
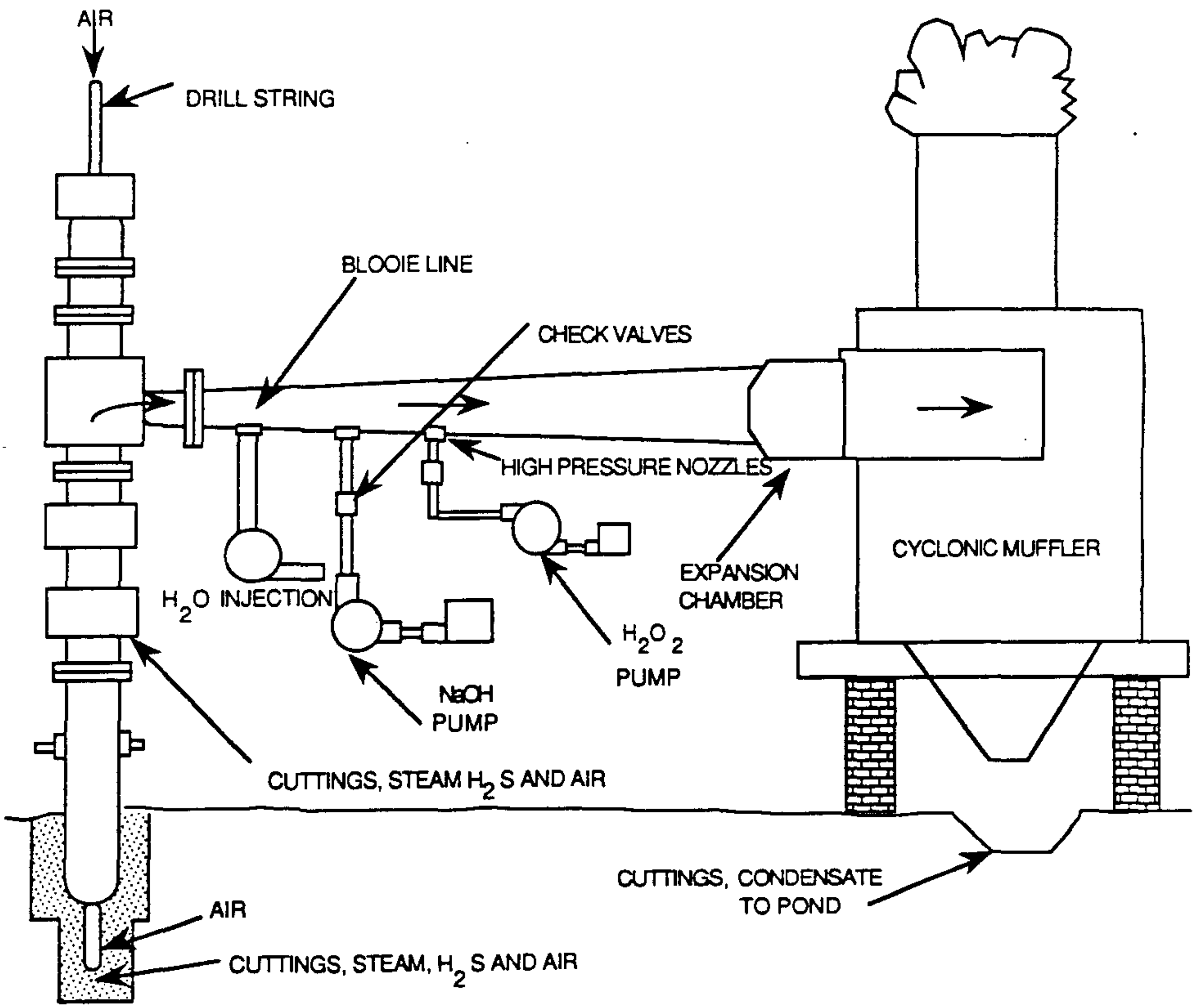


FIGURE 2



A TYPICAL GEOTHERMAL DRILLNG/MUFFLER SET-UP

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From: Norman J. Clark
Project Manager, Puna Geothermal Venture Construction
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To: Dr. John Lewin, M.D., Director, Hawaii DOH

From: Thomas G. Kizis
Permit Coordinator, Puna Geothermal Venture Construction
Weekly Well Monitoring Report May 13-20, 1991
To: Dr. John Lewin, M.D., Director, Hawaii DOH

From: William Templow
Field Manager, Puna Geothermal Venture Construction
Steam Condensate Analysis, Kapoho State 3 Flow Test
To: Clifford Furikado, Clean Air Branch,Hawaii DOH

From: Jana Malcolm Brown
Brewer Enviromental Services
Laboratory Analysis Report (1) Of Catchment Water
To: Dr. Rubin/Glen Tomori, Drinking Water Program, Hawaii DOH

From: Thomas G. Kizis
Permit Coordinator, Puna Geothermal Venture
Report on Uncontrolled Flow Event As Per Conditions #13 and #26, ATC No. A-833-795, Attachment II Wellfield
To: Dr. John Lewin, Director, Hawaii DOH

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Clean Air Branch, Hawaii DOH
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Puna Geothermal Venture Noise Monitoring Program
Well Blow Out Data Report: June 1991

GODDARD & GODDARD ENGINEERING
Environmental Studies

STATE OF HAWAII GEOTHERMAL ACTION PLAN
ELEMENT III PART II
MICROMETEOROLOGICAL AEROMETRIC AND HEALTH EFFECTS ANALYSIS

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ELEMENT III

PART II

STATE OF HAWAII

GEOTHERMAL ACTION PLAN

MICROMETEOROLOGICAL AEROMETRIC AND HEALTH EFFECTS ANALYSIS

CONTRIBUTION TO THE

INDEPENDENT AIR AND NOISE MONITORING PROGRAM REVIEW

CONCERNING THE JUNE 12, 13 AND 14, 1991 UNCONTROLLED VENTING

OF THE PUNA GEOTHERMAL VENTURES KS8 GEOTHERMAL WELL

SUBMITTED TO: Honorable Lorraine R. Inouye,
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ELEMENT III PART I AND PART II REPORTS INTEGRATION

The Element III report contains Part I, Independent Air and Noise Program Review of Concerning the June 1991 Uncontrolled Venting of the Puna Geothermal Ventures KS-8 Geothermal Well, prepared by Robert L. Reynolds, Chairman Element III review committee, Air Pollution Control Officer (APCO) and Noise Control Officer, Lake County Air Quality Management District, Lakeport, California; and Part II of Element III, State of Hawaii Geothermal Action Plan Micrometeorological Aerometric and Health Effects Analysis, prepared by Wilson B. Goddard, Ph.D., Principal, Goddard & Goddard Engineering - Environmental Studies, Lucerne, California. The Part I and Part II reports are in full agreement as to the major findings and recommendations.

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MICROMETEOROLOGICAL AEROMETRIC AND HEALTH EFFECTS ANALYSIS CONTRIBUTION TO THE INDEPENDENT AIR AND NOISE MONITORING PROGRAM REVIEW CONCERNING THE JUNE 12, 13 AND 14, 1991 UNCONTROLLED VENTING OF THE PUNA GEOTHERMAL VENTURES KS8 GEOTHERMAL WELL

ES 1.0 EXECUTIVE SUMMARY OF FINDINGS AND RECOMMENDATIONS

A micrometeorological aerometric analysis has been conducted on the uncontrolled Puna Geothermal Ventures (PGV) injection well uncontrolled venting starting at 2319 hrs on June 12, 1991 and ending at 1200 hrs on June 14, 1991. The purpose of this study is to provide independent verification of monitoring and spot measurements of ambient concentrations of hydrogen sulfide (H2S) as well as provide estimates of plume concentration and plume transport paths in areas where documented health effects occurred.

ES 2.0 SUMMARY OF FINDINGS

- o Independent estimates of hydrogen sulfide (H2S) ambient concentrations were shown to be in substantial agreement with local monitoring station and mobile spot measurements throughout the venting period.
- o Local H2S concentrations were elevated above health significance levels and correlated with health complaints.
- o Regional H2S transport of the KS8 venting plume cloud was documented by visual sighting, by regional and local wind assessments, and by the chronology and position of health complaints beyond 10 miles (16 km).
- o Estimates of the emissions of other air toxics and estimates of the impacts are shown to be of significant health concern.
- o The permittee is in apparent violation of permit requirements for H2S emission limits, for H2S air quality impacts, for exceeding noise limits in duration and in magnitude, has not utilized the Best Available Control Technologies and has not utilized equipment described in the Authority to Construct.

ES 3.0 SUMMARY OF RECOMMENDATIONS

It is recommended that PGV pay for any additional expense involved in implementing the following measures:

1. Emissions limits for H2S be enforced by DOH personnel.

2. A Puna Air Monitoring Program (PAMP) be formed and managed by DOH with participation by the developer, the local agencies, State agencies, local concerned organizations and local concerned residents. An Operational Management of Air Resources (OMAR) type system be established to link all PAMP stations to a central computer to which an emergency response system is linked. The central computer should archive monitoring data and allow near real-time access to data for air management activities by the developer, by responsible agencies and by local community groups.

3. Modify station positions and install additional meteorological monitoring equipment and sites to further study the geothermal air pollution meteorology of the location and zone of impact.

4. The PAMP committee manage local and regional air transport special studies.

5. The PAMP committee should quality assure monitoring data, document all quality assurance procedures and publish sufficient volumes of the monitoring documents and special studies so that developers, engineers and environmental scientists have access to the documents.

1.0 INTRODUCTION

A micrometeorological aerometric analysis has been conducted on the Puna Geothermal Ventures (PGV) injection well uncontrolled venting starting at 2319 hrs on June 12, 1991 and ending at 1200 hrs on June 14, 1991. The purpose of this study is to provide independent verification of monitoring and spot measurements of ambient concentrations of hydrogen sulfide (H2S) and other air toxics as well as provide estimates of plume concentration and plume transport paths in areas where documented health effects occurred.

The uncontrolled venting incident at the KS8 well released an estimated 200,000 lb/hr (95,300 kg/hr) of steam and brine containing 180 lb/hr (81.7 kg/hr) of H2S in a complex plume cloud which was estimated to have emissions extending from ground level to a height of 65 ft (19.8 m). An estimate of the emissions of air toxics is contained in Table 1-1. The estimates in Table 1-1 are based upon wells KS-3 and KS-1A recent well chemistry and on Table 4-4 of the March 1989 PGV Authority to Construct.

TABLE 1-1

ESTIMATED EMISSIONS OF AIR TOXICS

RELEASED DURING THE KS8 UNCONTROLLED VENTING

Estimates based upon a steam flow rate of 210,000 lb/hr using geochemical data from KS-3, KS-1A and Authority to Construct.

Component	Emission Rate	
	lb/hr	kg/hr
Hydrogen sulfide	180	81.7
Lead	13.6	6.16
Nickel	1.80	0.817
Chromium	1.44	0.654
Manganese	2.36	1.07
Copper	0.326	0.148
Zinc	0.384	0.174
Arsenic	0.008	0.004
Mercury	0.001	0.0005
Silicon Oxide	30.0	13.6
Total Dissolved Solids	700	318

Note:
Estimated worst case 100% flash;
Table 4-4, page 4-10, March 1989 AtC

2.0 STUDY METHODOLOGY

The methodology of the micrometeorological aerometric analysis utilizes the Micrometeorological Air Dispersion Assessment Methodology (MADAM) which follows guidelines established by regulatory agencies for air quality impact analysis (Appendix A).

Information characterizing the KS8 emissions and the initial plume rise were obtained from Robert L. Reynolds' on-site assessment, the PGV emission estimates, and from photographs and videos of the well emissions. Meteorological data from the Southwest, Alvarez and Wade monitoring sites were used to estimate the initial wind speed, wind direction, standard deviation of wind direction (sigma), air temperature, relative humidity and precipitation.

The distribution of atmospheric pollutants from their sources to the receptor areas, and their paths of travel and concentration, are dependent upon the wind flow regime and upon the pollutants' vertical and horizontal dispersion. The dispersion of atmospheric pollutants both vertically and horizontally is dependent upon the state of atmospheric stability:

- **unstable** atmospheric conditions [temperature decreasing with height at a rate **greater** than the adiabatic lapse rate of 5.4 °F/1,000 feet (1 °C/100 meters)] greatly **enhance** dispersion;

- **stable** atmospheric conditions [temperature decreasing with height at a rate **less** than the adiabatic lapse rate] greatly **diminish** dispersion.

Unstable conditions prevail during the afternoon periods, while stable conditions occur at night and in the early morning hours. Stable conditions aloft, called temperature inversions, tend to cap upward dispersion of pollutants.

The estimation of air quality impacts follows procedures recommended by the Environmental Protection Agency (EPA) (Goddard, 1986 and 1987). Errors are estimated and presented as ± values which indicate that there is a 68% probability that values will lie within these limits. Atmospheric Stability Classifications A through F are used where A is extremely unstable, D is neutral and F is moderately stable.

Hydrogen sulfide is considered the most critical air pollutant contained in the geothermal resource emissions. Other gaseous and small particulate pollutants discussed will disperse similarly and will be compared to the estimates made for hydrogen sulfide (H_2S). The air quality impact analysis estimates are compared to the monitoring data from the Southeast, Southwest, Wade, Alvarez and Irvine stations, and to spot measurements taken throughout the event period.

The uncertainty in each estimated plume isopleth concentration is proportional to the concentration and will average 50%. This is the nature of turbulent transport. Tables of estimated concentrations contain uncertainty estimates.

The health effects of the toxic pollutant emissions are discussed in Section 4 and compared to referenced literature. The results of complaint surveys and the type of health effect are discussed. Many groups and individuals assisted on circulating, collating and compiling the health survey information.

The hydrogen sulfide air quality impacts are discussed in terms of the U.S. Occupational Safety and Health Agency (OSHA) 10 ppm worker Permissible Exposure Limit (PEL) (Threshold Limit Value), the 15 ppm Short Term Exposure Limit (SPEL) (10 minutes per 8 hour) and the 50 ppm Ceiling Limit. In the absence of a State of Hawaii H2S Ambient Air Quality Standard (AAQS), the H2S OSHA standard of 10 ppm is divided by 4.2 (168 hour per week exposure / 40 hour worker week) times 100 (accounts for documented adverse health effects at the PEL (TLV) OSHA standard thus requiring additional protection for those which are more sensitive such as children and older persons) = 420. This equates for H2S to 10 ppm / 420 = 24 ppb (34 ug/m3) suggested health safety limit for the general public.

3.0 AIR QUALITY IMPACT ANALYSIS

The H2S measurements made at the monitoring stations and spot measurements made by personnel during the event were compared to air quality impact estimates. Meteorological data from the Wade Station, the Southwest PGV station and the Alvarez station were used in determining the local micrometeorological conditions. Winds along the coast were obtained from the National Weather Service station at the U.S. Coast Guard Reservation at Cape Kumukahi. The estimates of emissions listed in Table 1-1 were used in the impact analysis.

3.1 METEOROLOGICAL CONDITIONS DURING THE EVENT

During the first hour of the event which started at 2319 hrs on June 12, 1991, the winds were from the north-northwest, 330 deg at 6.25 mph (2.79 mps) at the SW station (ending time of 0000 hrs). The wind speed remained fairly uniform with a low of 4.73 mph (2.11 mps) at 0400 hrs on June 13, 1991. Wind directions remained out of the northwest sector until 1000 hrs when the trade wind influence shifted the direction into the north-northeast sector.

The trade wind influence continued throughout the afternoon and evening with increasing wind speed peaking at 13.4 mph (5.96 mps) at the hour ending at 1300 hrs. Evening winds decreased in speed with a return of north-northwest winds briefly occurring at the hour ending at 2300 hrs. At that time at the SW station the winds were from 350 deg at 5.49 mph (2.45 mps). Low wind speeds persisted throughout the early morning hours of June 14, 1991 with a low of 3.88 mph (1.79 mps) again from the north-northeast sector.

Data on coastal winds was obtained from the U.S. Coast Guard Reservation at Cape Kumukahi, 6 miles (10 km) to the northeast of the event. Along the coast, the winds were from the north-northwest during the first seven hours of the event at 12 mph (10 knots). At 0700 hrs, the coastal winds became northerly increasing to 16 mph (14 knots) through the day and decreasing at night to a minimum of 9 mph (8 knots) by midnight.

Ambient temperature at the beginning of the event was 66 deg F (19 deg C) and the relative humidity was 88%. Dew or mist deposition occurred periodically at 0.25 mm (0.01 in) per hour. A drizzle occurred between 2200 hrs and 2300 hrs on June 13, 1991 which resulted in 2.57 mm (0.10 in) peaking between 0100 and 0200 hrs on June 14, 1991 at 11 mm (0.43 in) of precipitation. From 0200 hrs onward, no further dew or drizzle was indicated in the monitoring records.

All stations were used in the local and regional transport analysis. The Wade, Alvarez and SW stations' wind speed, wind direction and sigma were used. The SW station was used for initial local plume dispersion assessments since it was the closest station to the release site. The rolling and pocketed nature of the site and the prominence and proximity of craters and volcanic cones result in wind flow (orographic) differences between stations in both wind speed and direction.

Each local estimate of impact used the extremes in wind direction and sigma, and is shown as a range on the impact figures. The standard deviation of the horizontal wind direction (sigma) was used to estimate the outer bounds of plume movement. One half of the sigma was added to the outer boundaries of direction which indicates a 68% probability that the plume centerline will be confined within these boundaries.

Each station exhibited high sigma values which are attributed to the gustiness and meandering nature of the wind flow. The high humidity and presence of dew and drizzle are indicative of micrometeorological conditions at night that are slightly stable, Pasquil Stability Class E. During the day the conditions were estimated to be slightly unstable, Pasquil Stability Class C. Neutral conditions, Pasquil Stability Class D, were estimated to occur in the morning and in the early evening.

The meteorological conditions during the event were not "worst case" poor air dispersion. Using Figure 3-1, the frequency of annual nighttime wind directions, the conditions would be expected to occur about 3 to 4% of the time. The highest directional occurrence at night is winds from the west sector. During the daytime hours, Figure 3-2 indicates that the conditions would occur 3% of the time except for the period when the trade conditions prevailed which is the highest occurrence event with a frequency of over 6%. Wind speeds could have been very low or calm which would have increased proportionally the severity of the impacts.

3.2 LOCAL AIR QUALITY IMPACT ASSESSMENT

The results of the comparison for near-site air quality impacts are shown in Figures 3-3 through 3-16. The outer plume lines denote the plume transport direction plus half the wind direction standard deviation (sigma). The outer plume lines indicate where meanders of plume direction may stray at the 68% probability level. The estimated isopleths of H2S concentration are shown on the figures for 500 ppbv, 100 ppbv, 50 ppbv and 25 ppbv. Each isopleth extends 1.0 mile (1.6 km) from the source.

The square brackets, [25 ppb] for example, indicate a monitoring site or a mobile measurement. The isopleth values are shown with the units below the number. The isopleths are based upon hourly averages since this more nearly conforms to ambient air quality standards. The estimated plume centerline concentrations are indicated by arrows. The nature of turbulent air transport gives rise to plume meanders and looping. The outer bounds of the estimated plume position indicate where the plume may stray. Within the indicated delineated boundary, the isopleths of concentration can and will move throughout the area with the upwind source area fixed.

The relationship of estimated plume position and estimated plume ground level H2S concentration are in agreement with the monitoring stations and the spot measurements. The relative width of the plume out to the 25 ppbv isopleth is narrow enough that it is usual that during emergency events many fixed or mobile monitoring sites miss the event or underestimate the impacts.

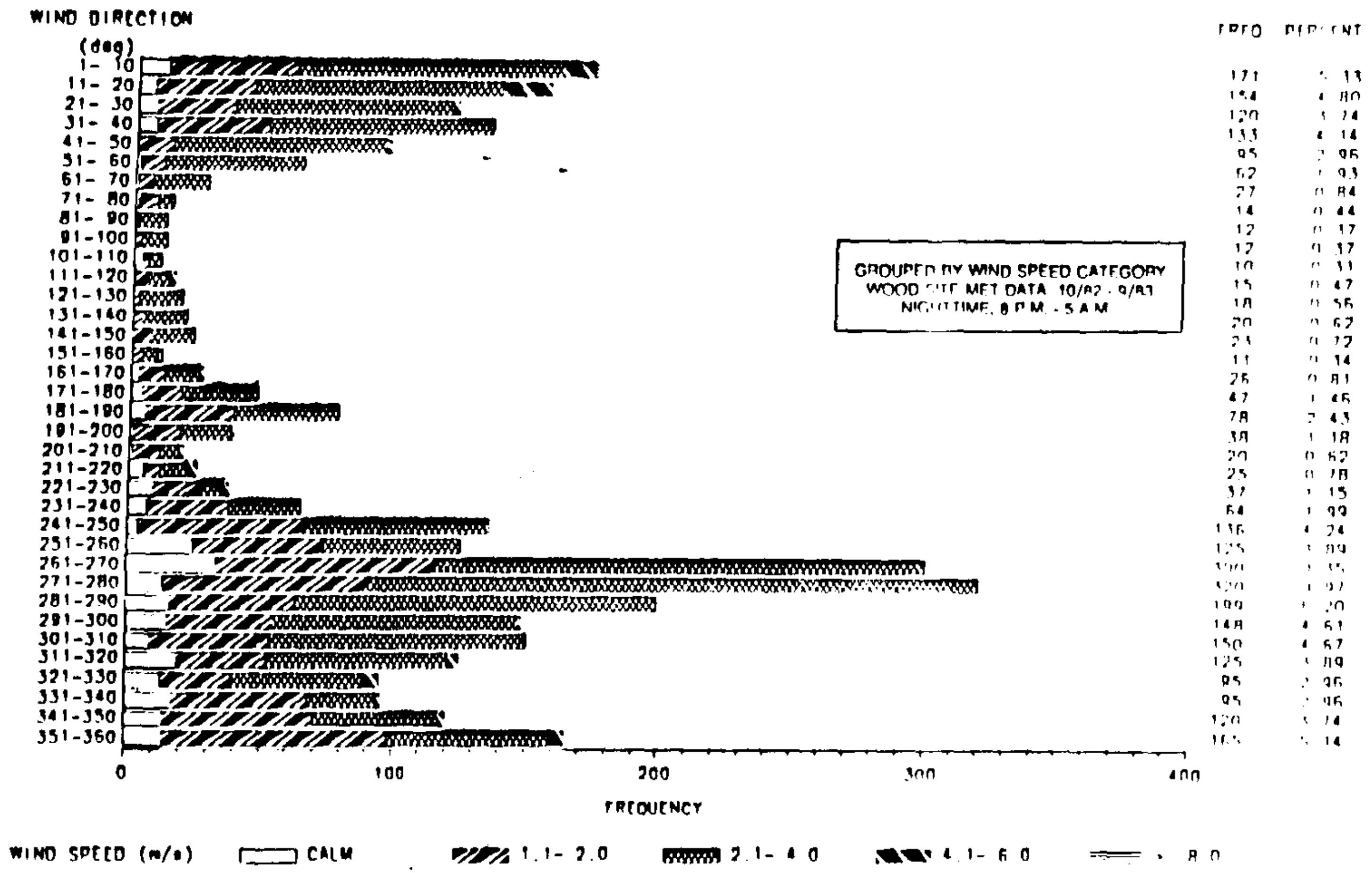

FIGURE 3-1 FREQUENCY OF ANNUAL NIGHTIME WIND DIRECTIONS

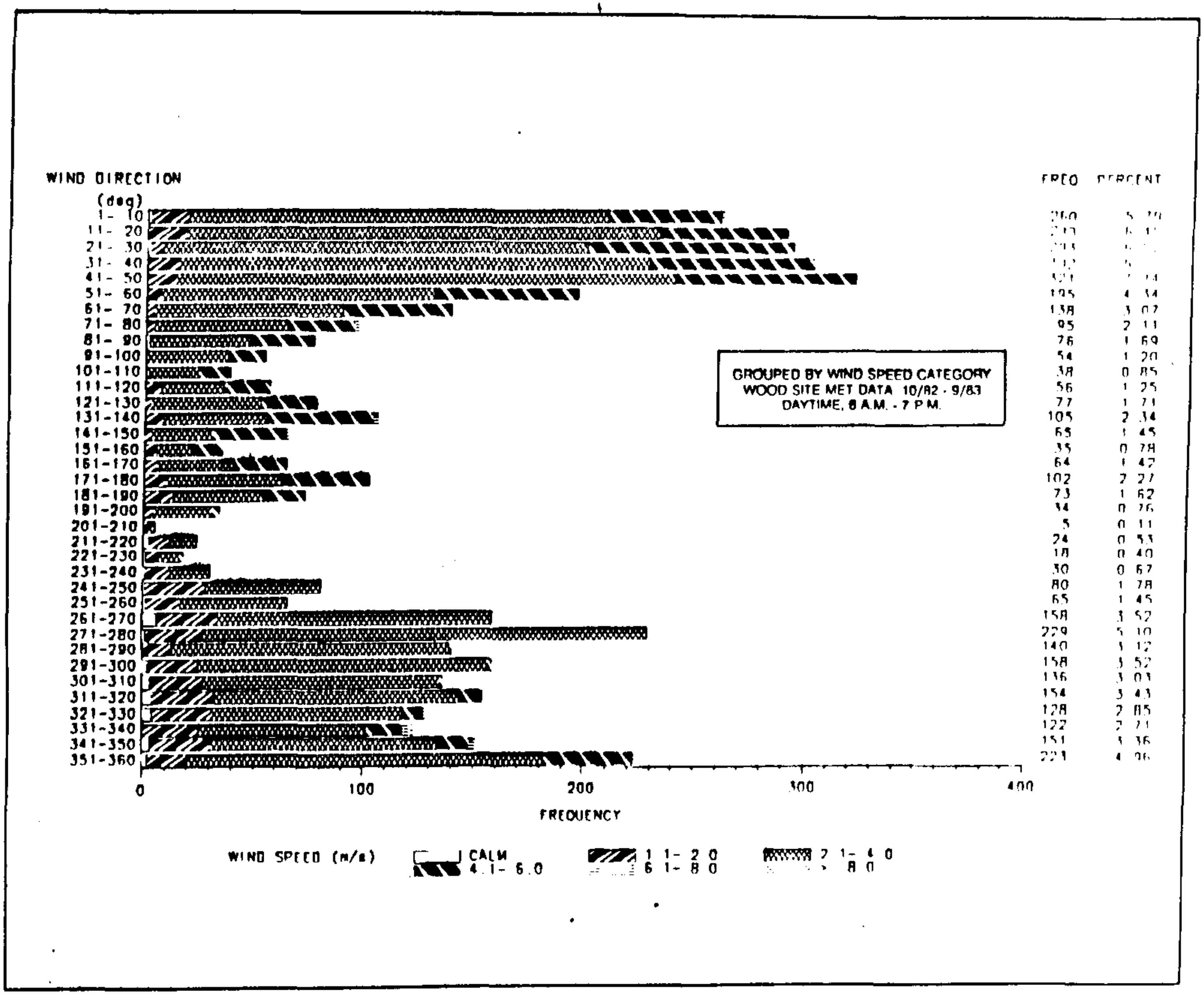

FIGURE 3-2 FREQUENCY OF ANNUAL DAYTIME WIND DIRECTIONS

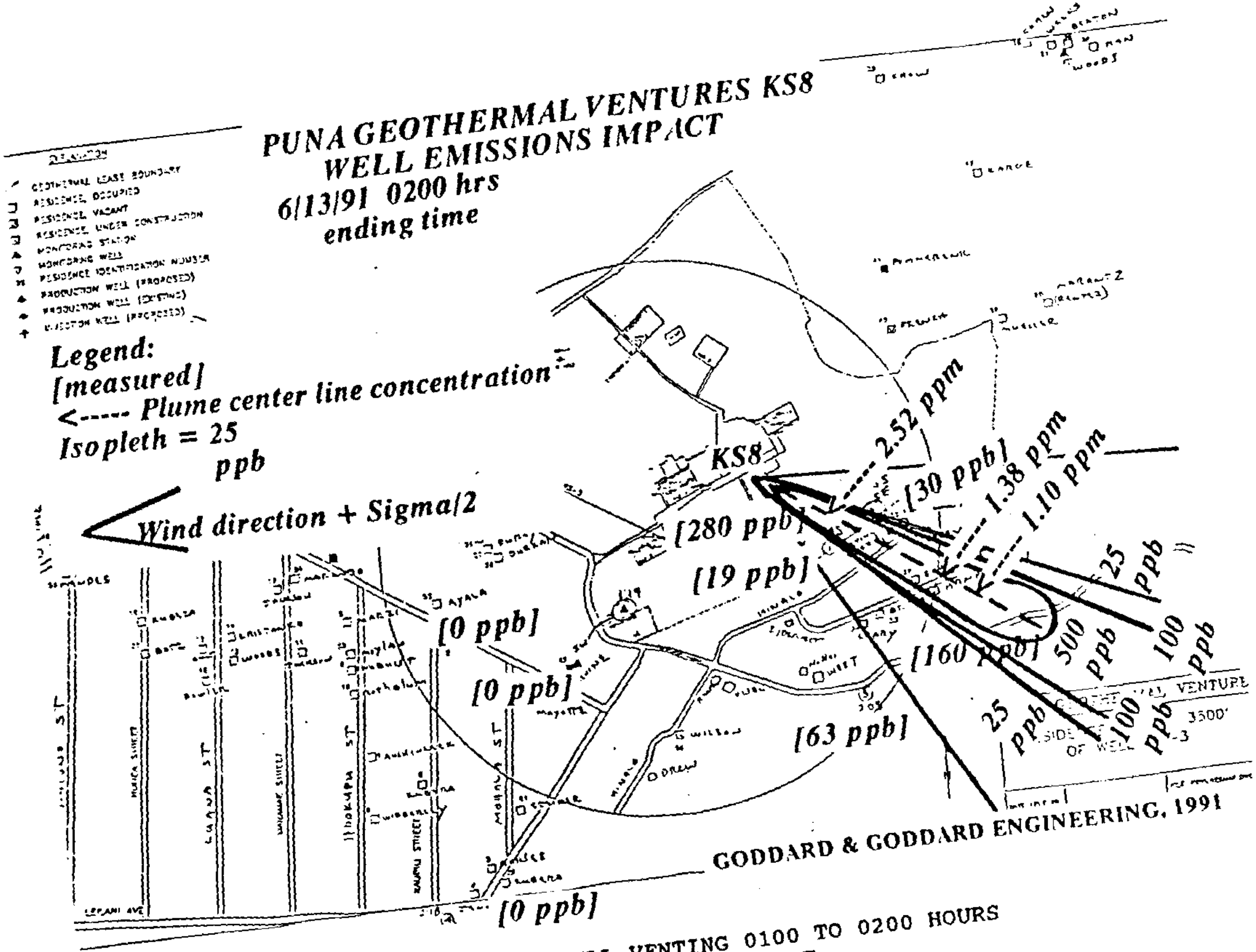

FIGURE 3-3 PGV KS8 WELL VENTING 0100 TO 0200 HOURS
JUNE 13, 1991 LOCAL IMPACT

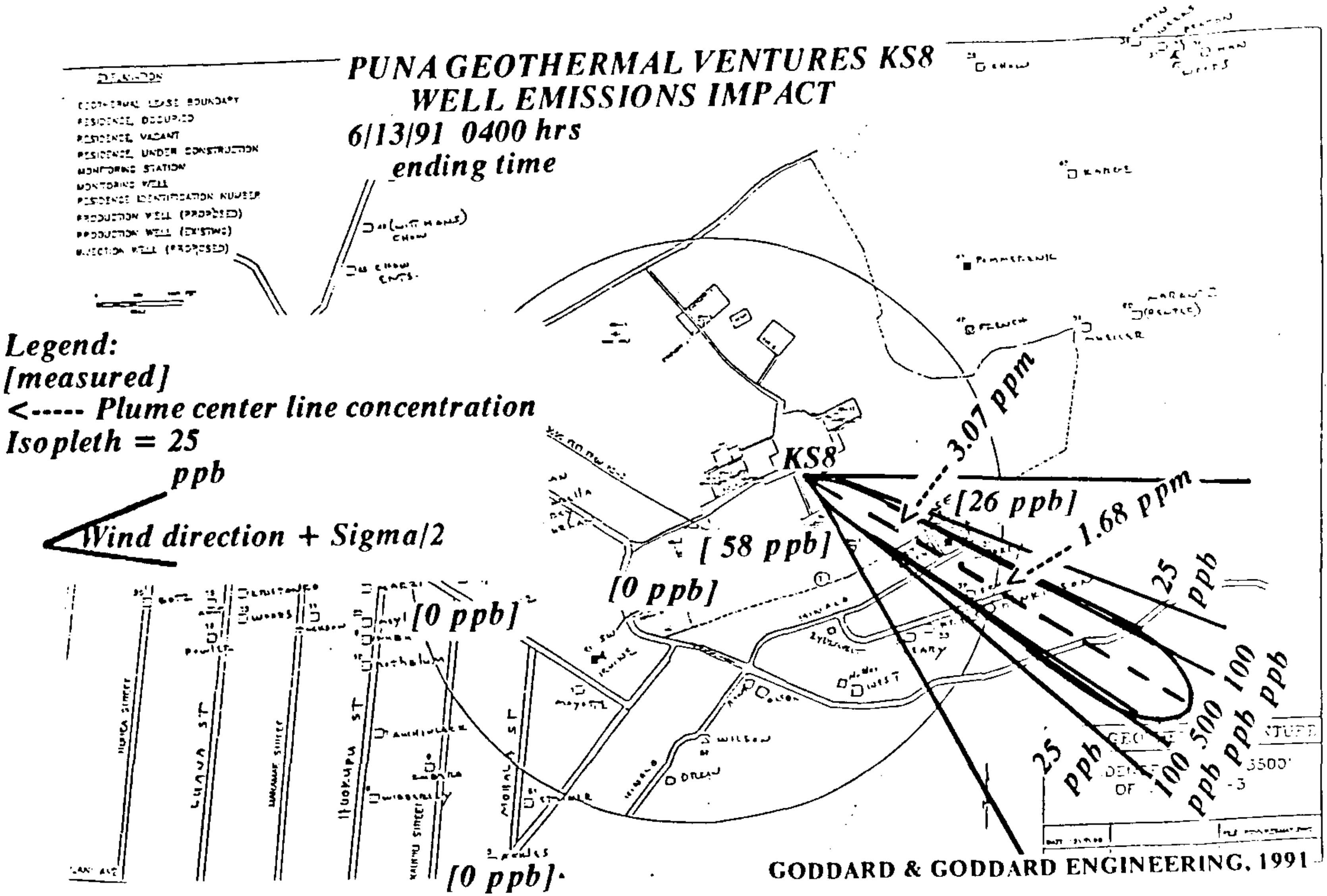

FIGURE 3-4 PGV KS8 WELL VENTING 0300 TO 0400 HOURS
JUNE 13, 1991 LOCAL IMPACT

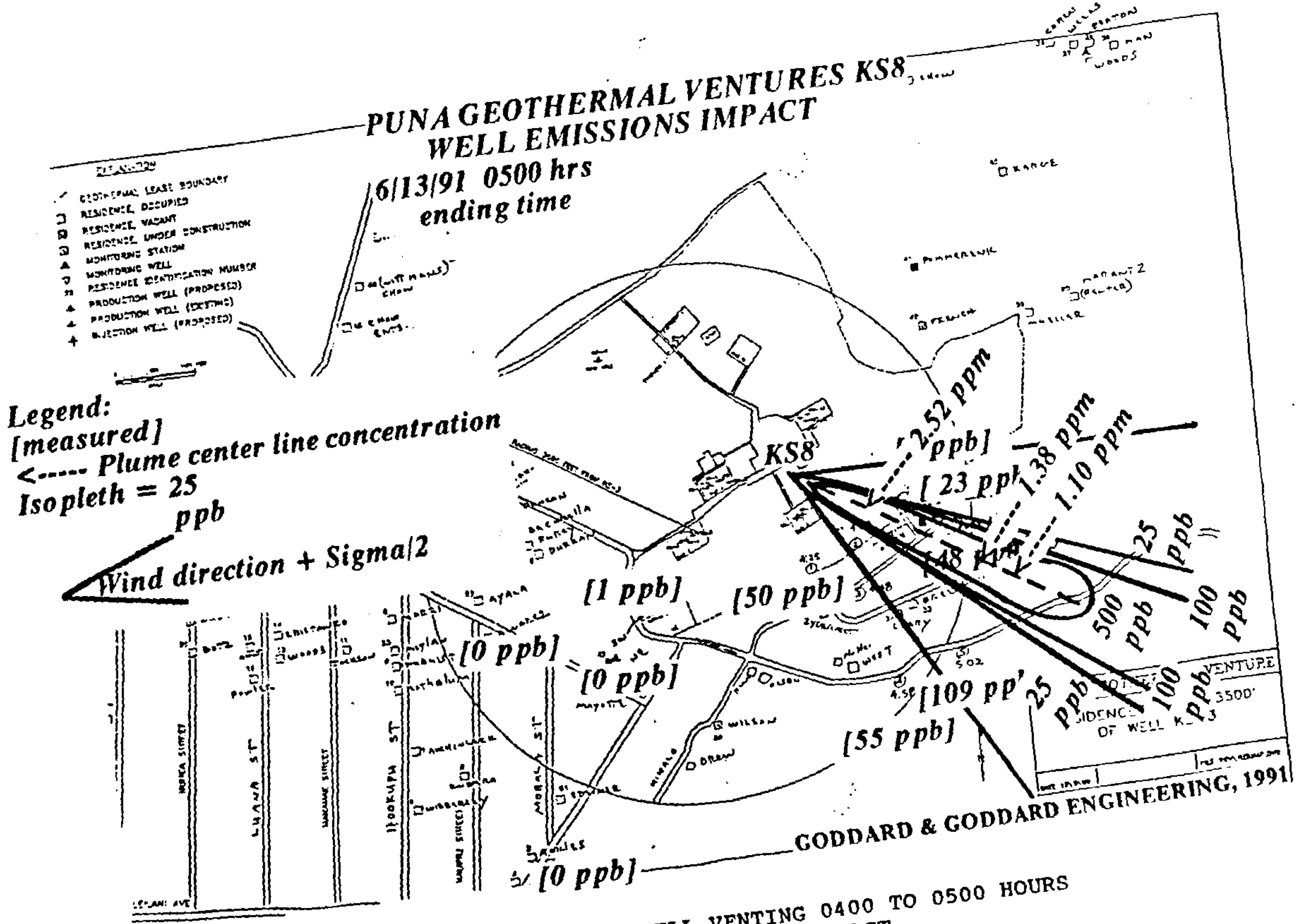

FIGURE 3-5 PGV KS8 WELL VENTING 0400 TO 0500 HOURS
JUNE 13, 1991 LOCAL IMPACT

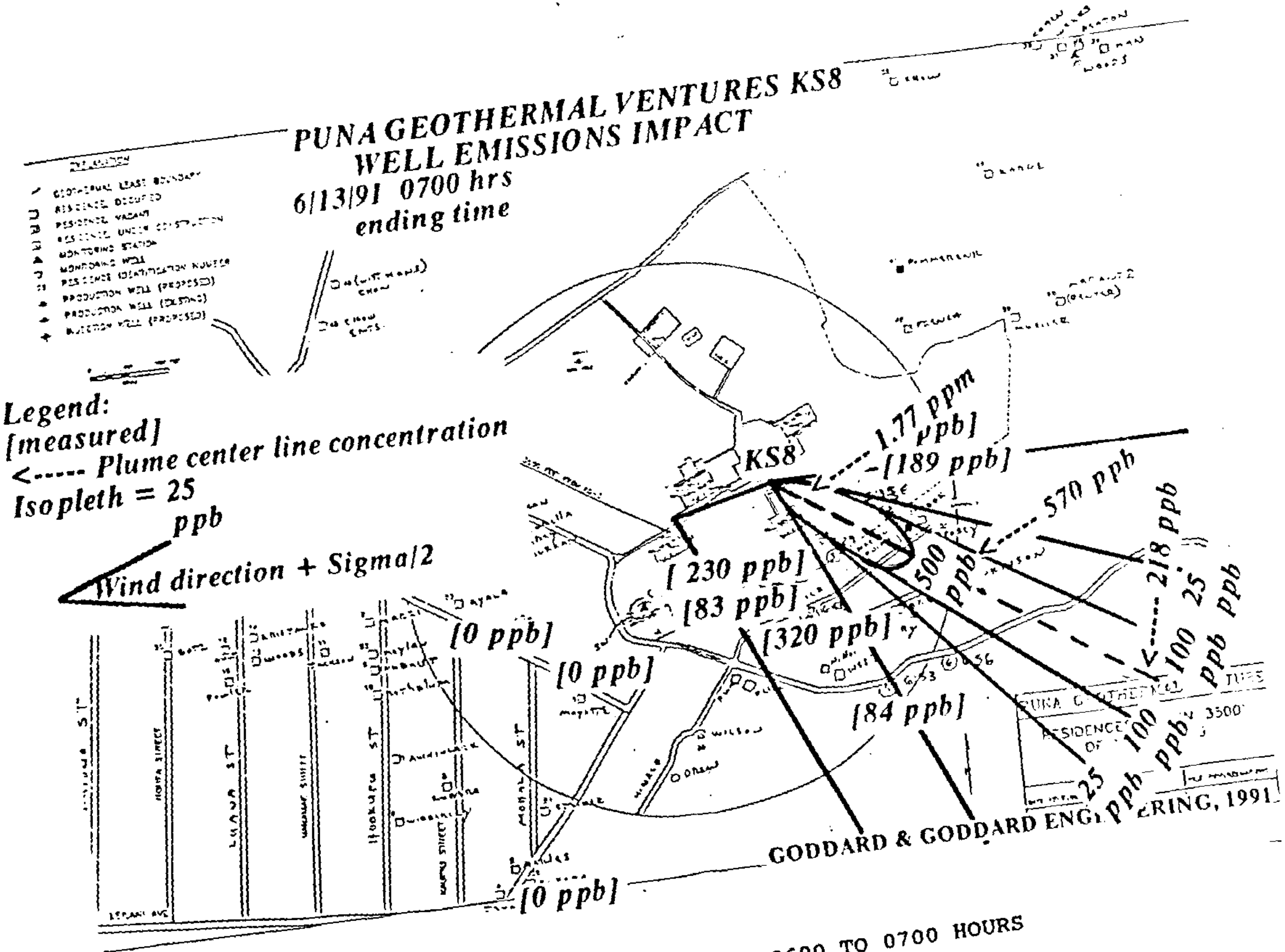

FIGURE 3-6 PGV KS8 WELL VENTING 0600 TO 0700 HOURS
JUNE 13, 1991 LOCAL IMPACT

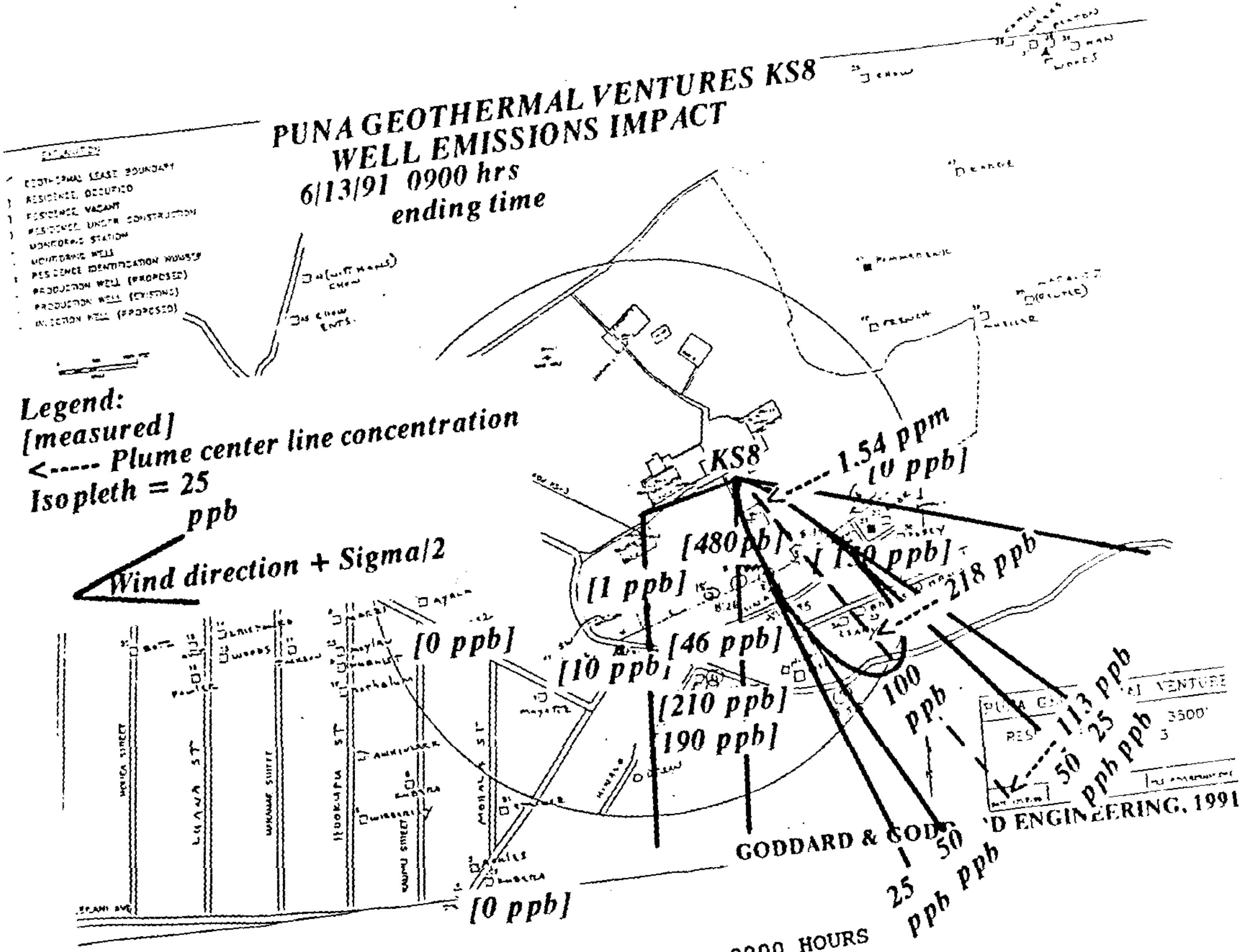

FIGURE 3-7 PGV KS8 WELL VENTING 0800 TO 0900 HOURS
JUNE 13, 1991 LOCAL IMPACT

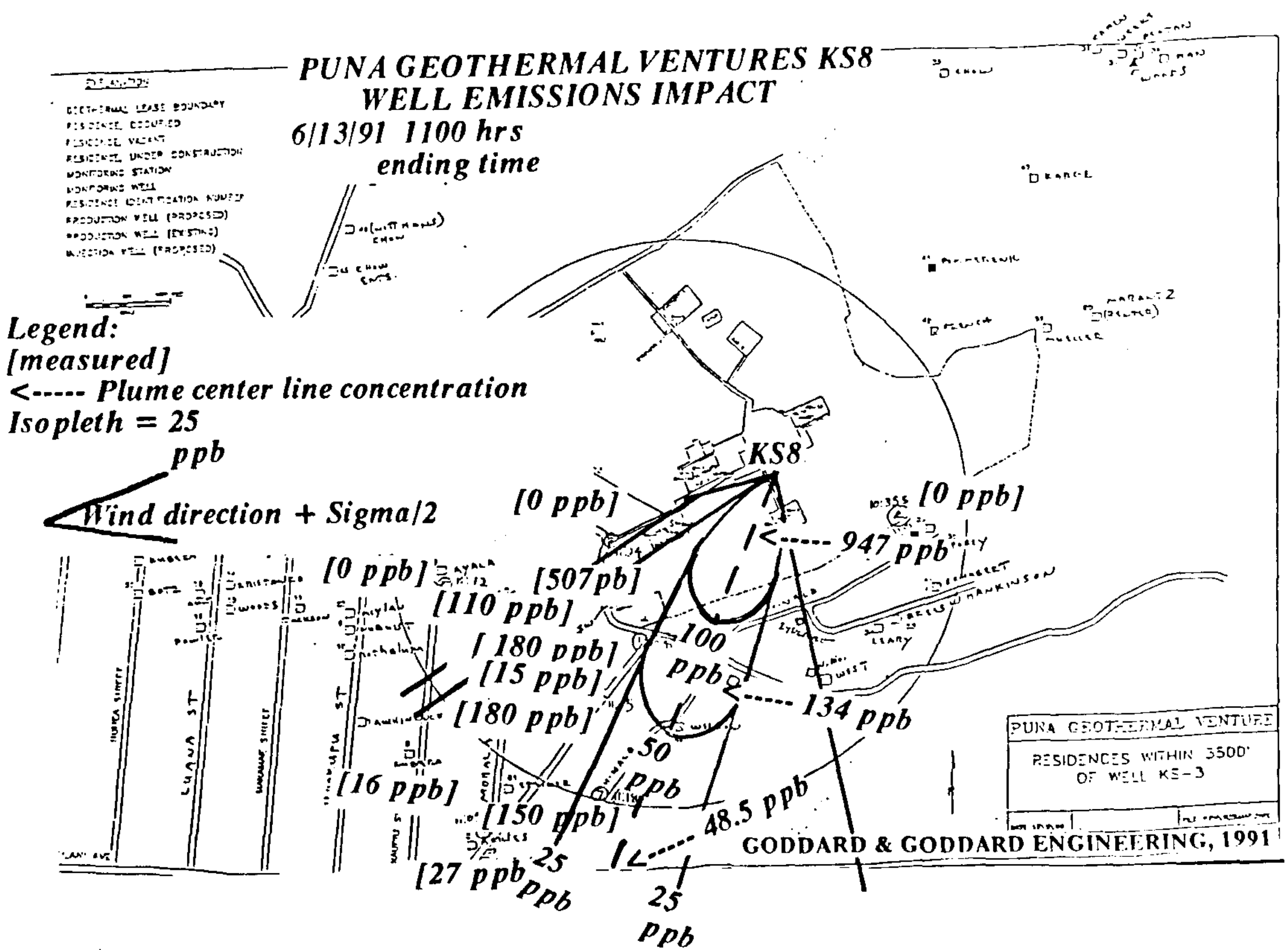

FIGURE 3-8 PGV KS8 WELL VENTING 1000 TO 1100 HOURS
JUNE 13, 1991 LOCAL IMPACT

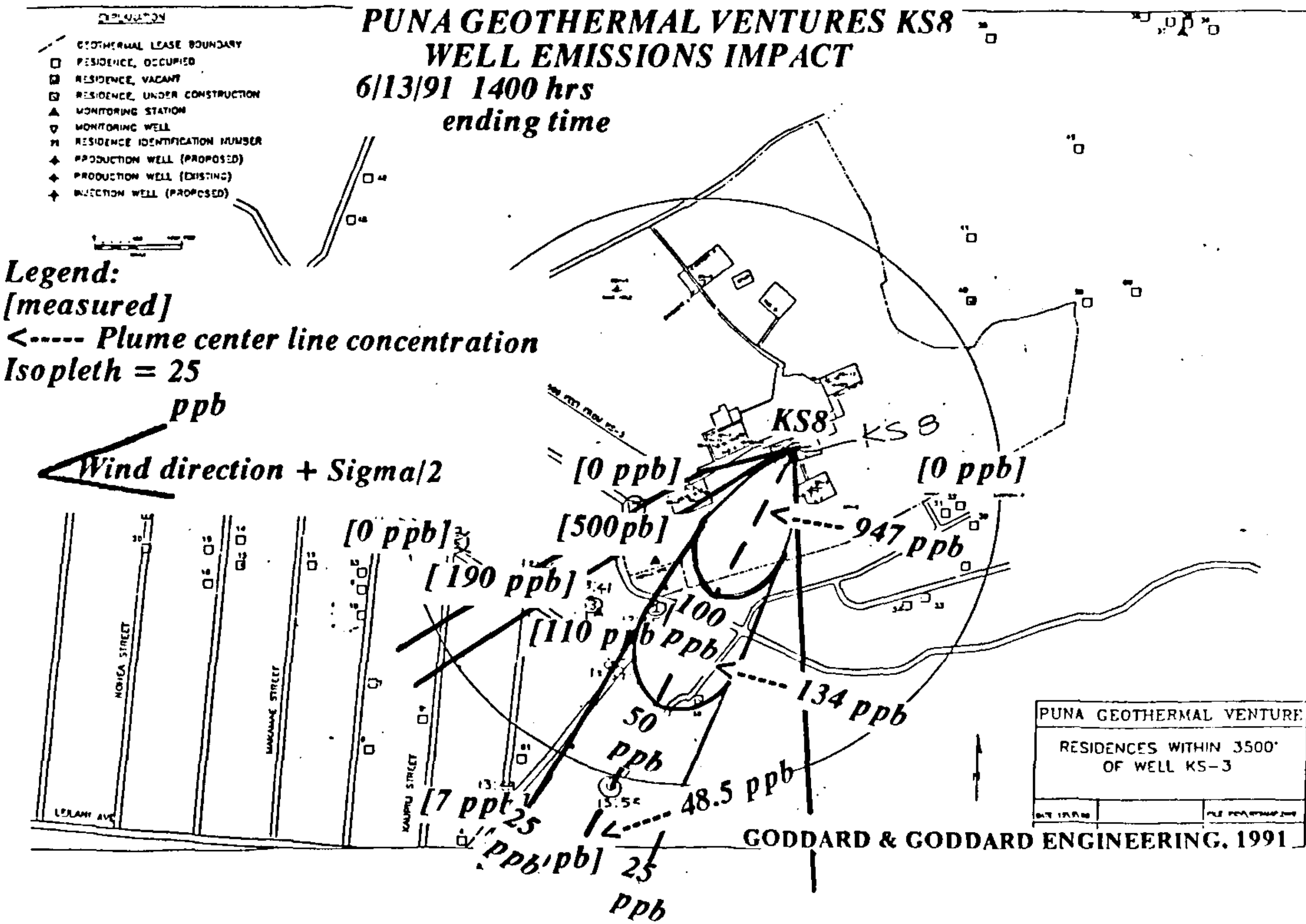

FIGURE 3-9 PGV KS8 WELL VENTING 1300 TO 1400 HOURS
JUNE 13, 1991 LOCAL IMPACT

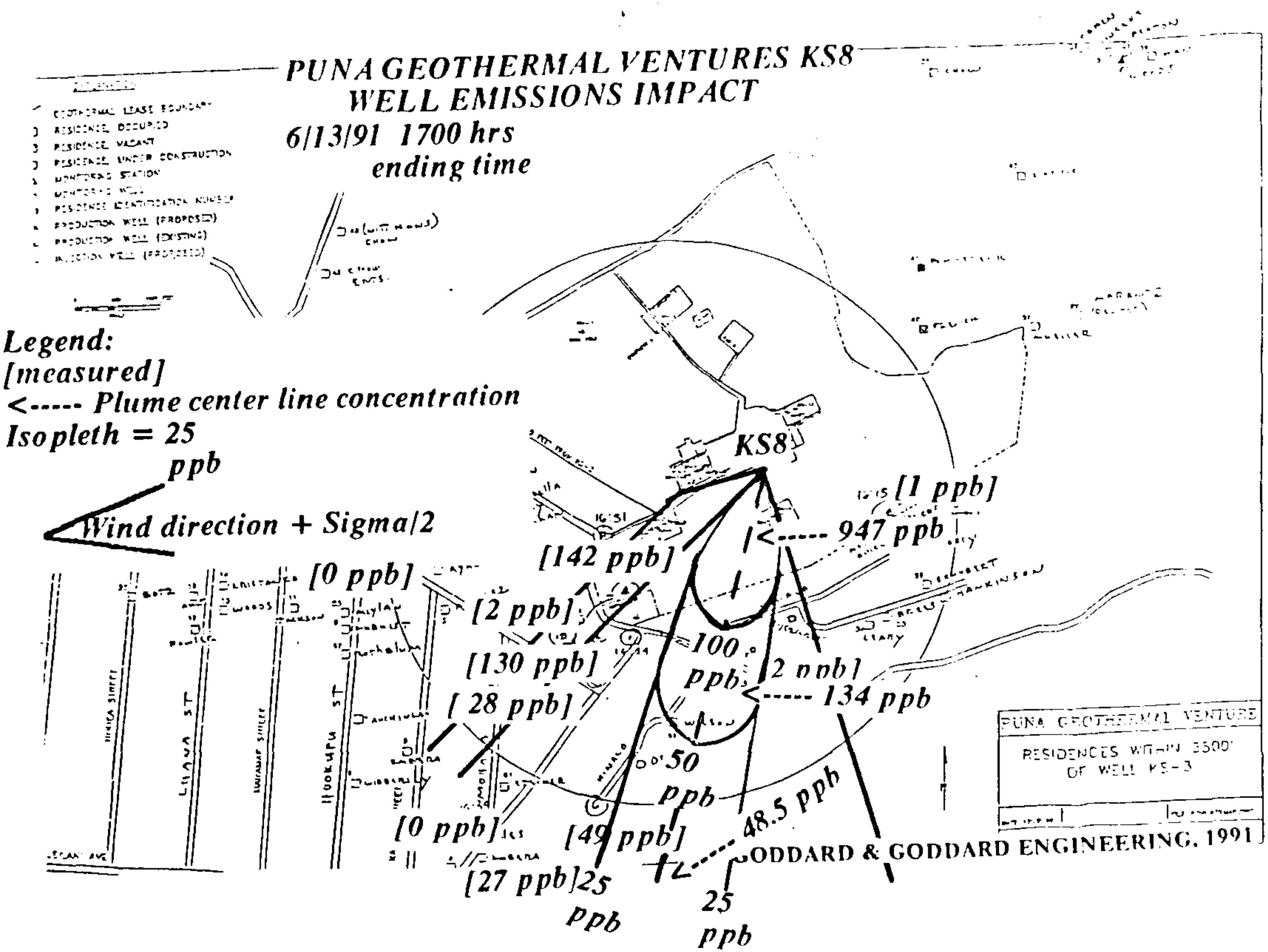

FIGURE 3-10 PGV KS8 WELL VENTING 1600 TO 1700 HOURS
JUNE 13, 1991 LOCAL IMPACT

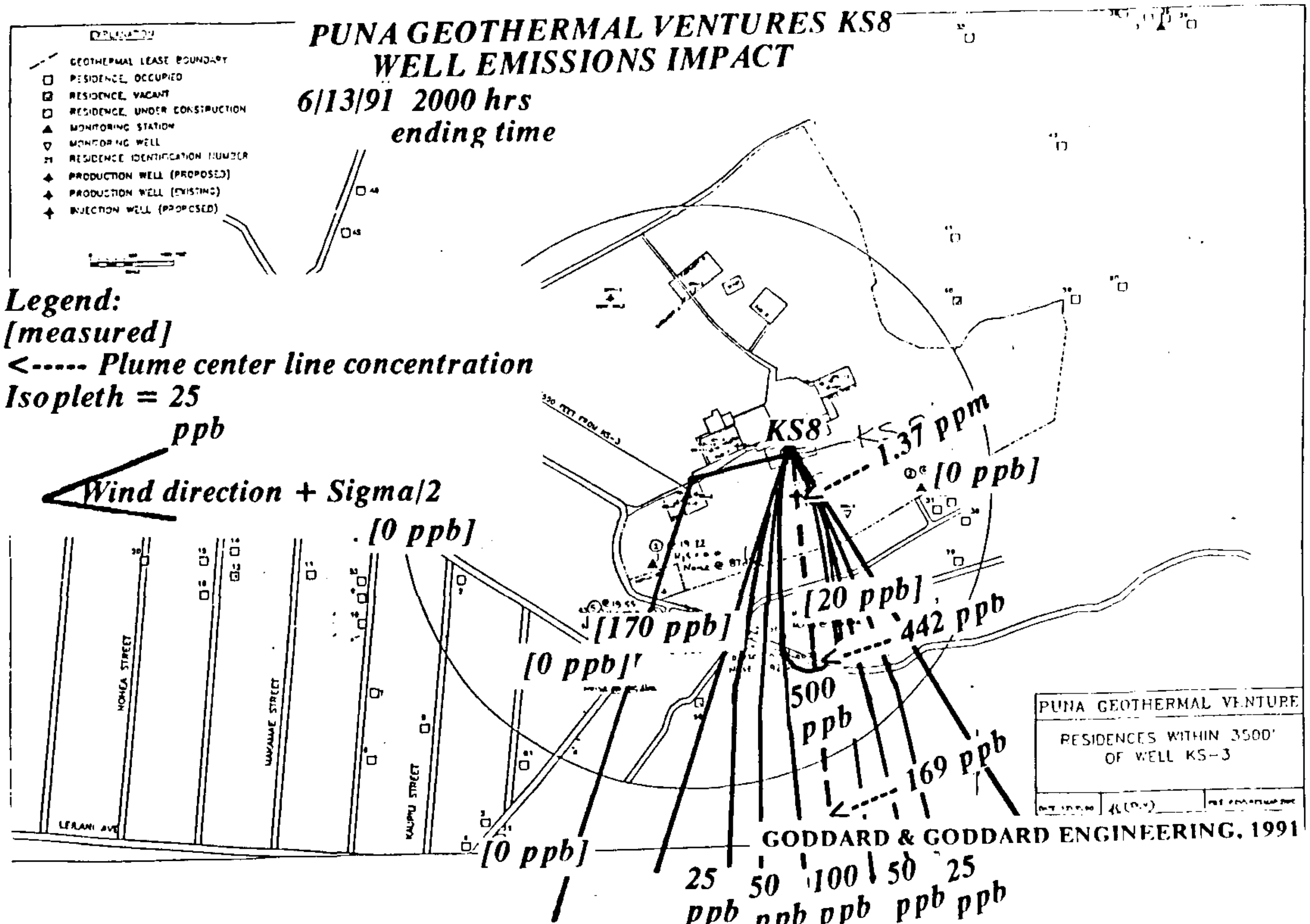

FIGURE 3-11 PGV KS8 WELL VENTING 1900 TO 2000 HOURS
JUNE 13, 1991 LOCAL IMPACT

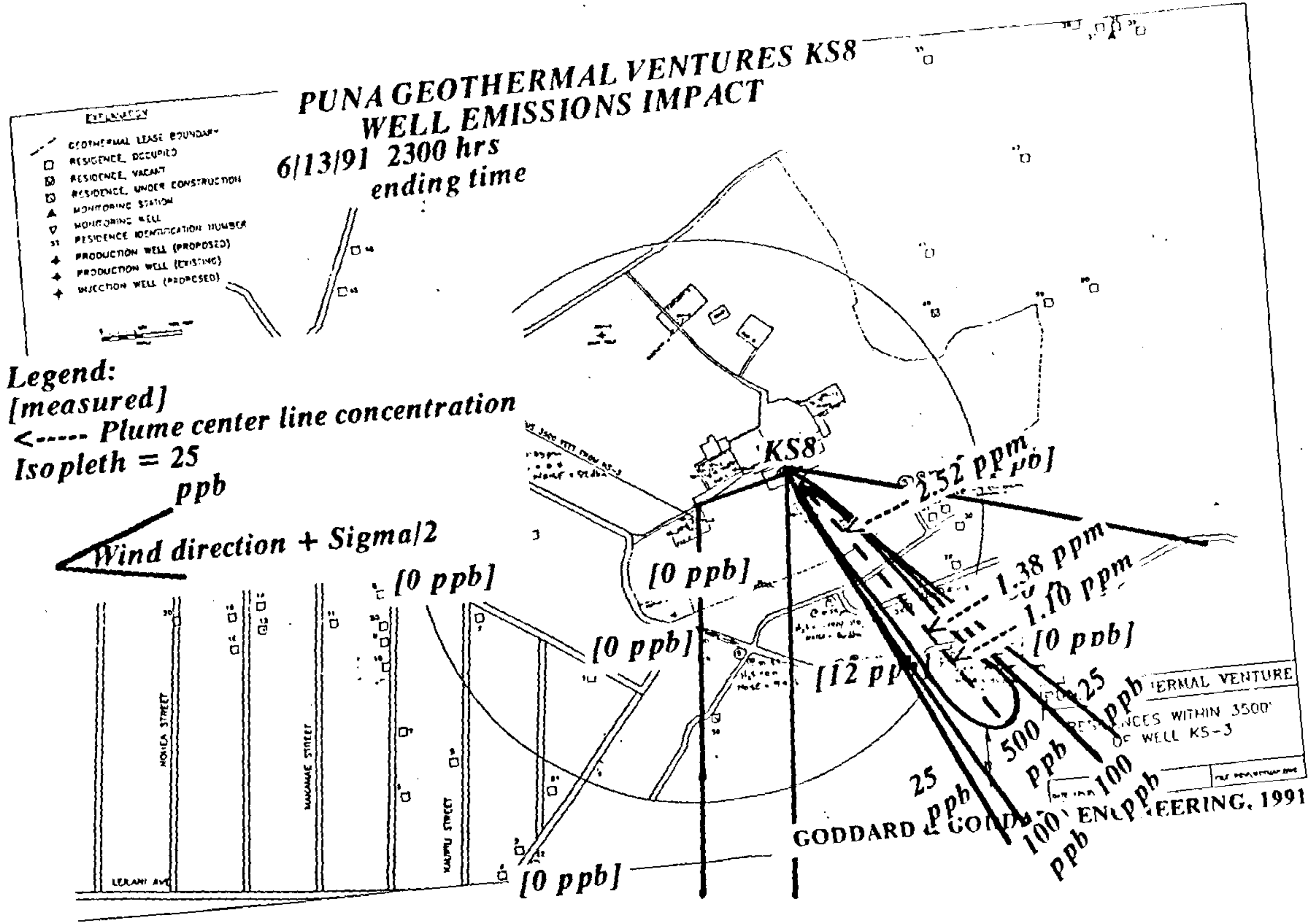

FIGURE 3-12 PGV KS8 WELL VENTING 2200 TO 2300 HOURS
JUNE 13, 1991 LOCAL IMPACT

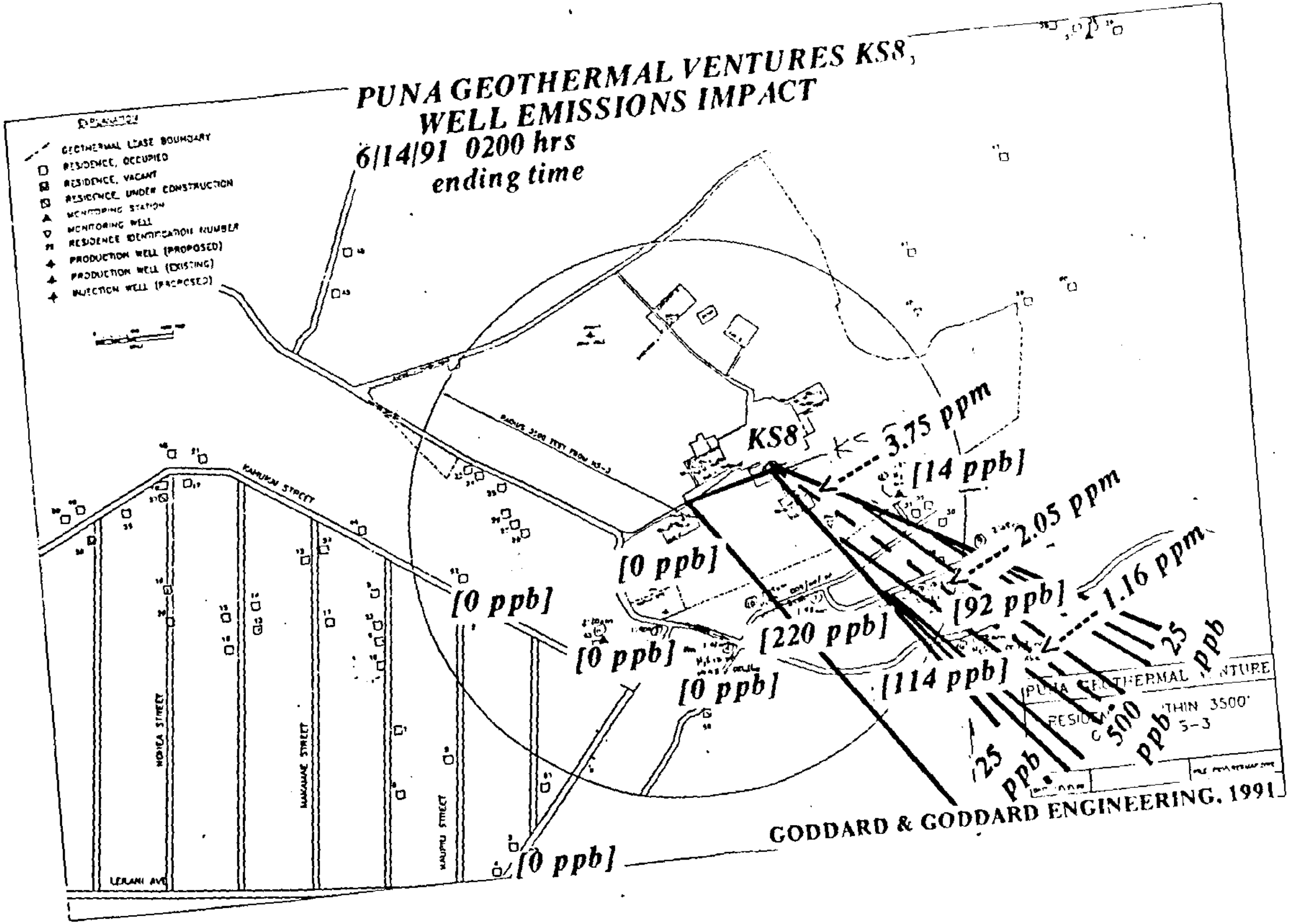

FIGURE 3-13 PGV KS8 WELL VENTING 0100 TO 0230 HOURS
JUNE 14, 1991 LOCAL IMPACT

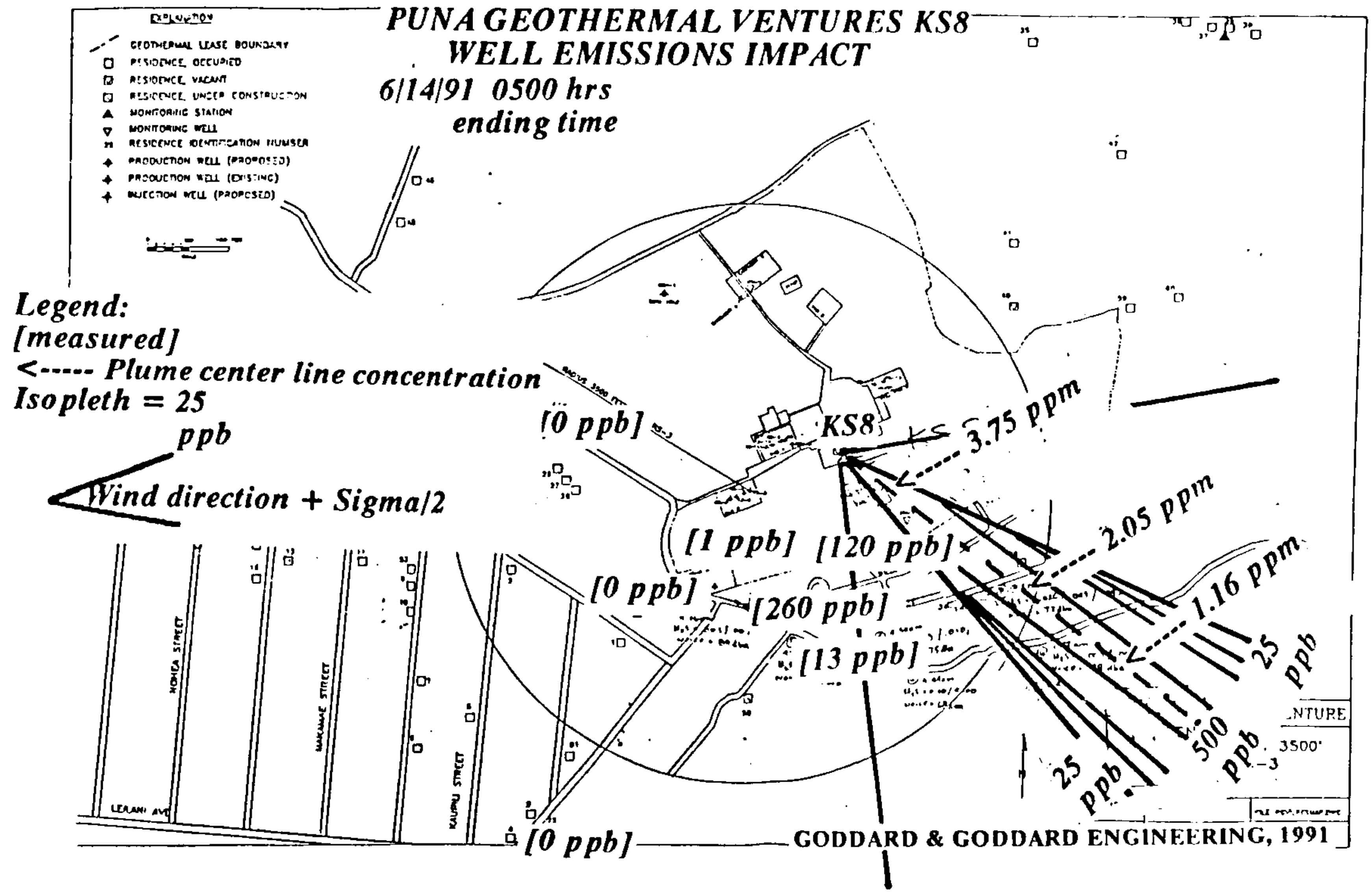

FIGURE 3-14 PGV KS8 WELL VENTING 0400 TO 0530 HOURS
JUNE 14, 1991 LOCAL IMPACT

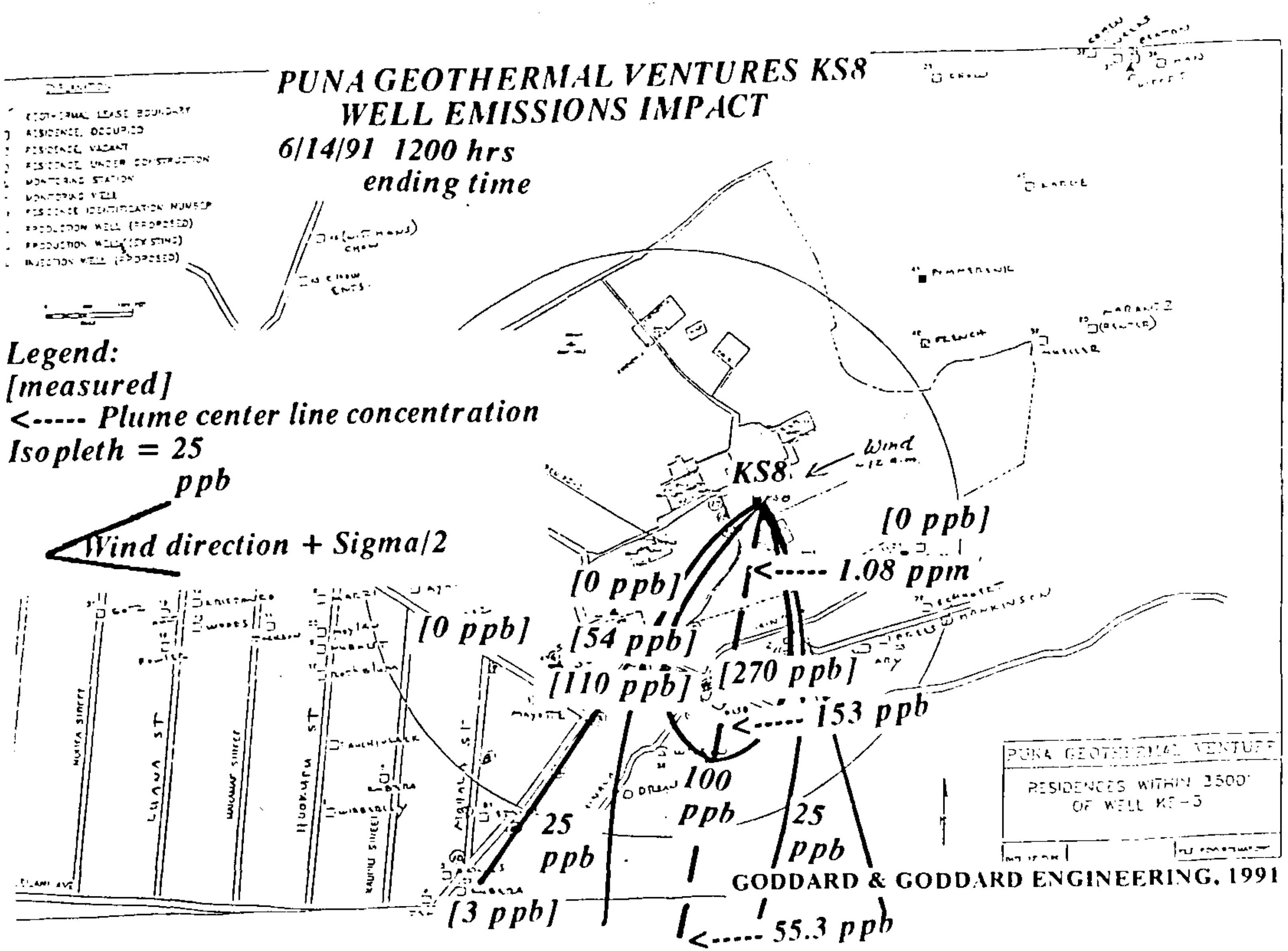

FIGURE 3-15 PGV KS8 WELL VENTING 1000 TO 1200 HOURS
JUNE 14, 1991 LOCAL IMPACT

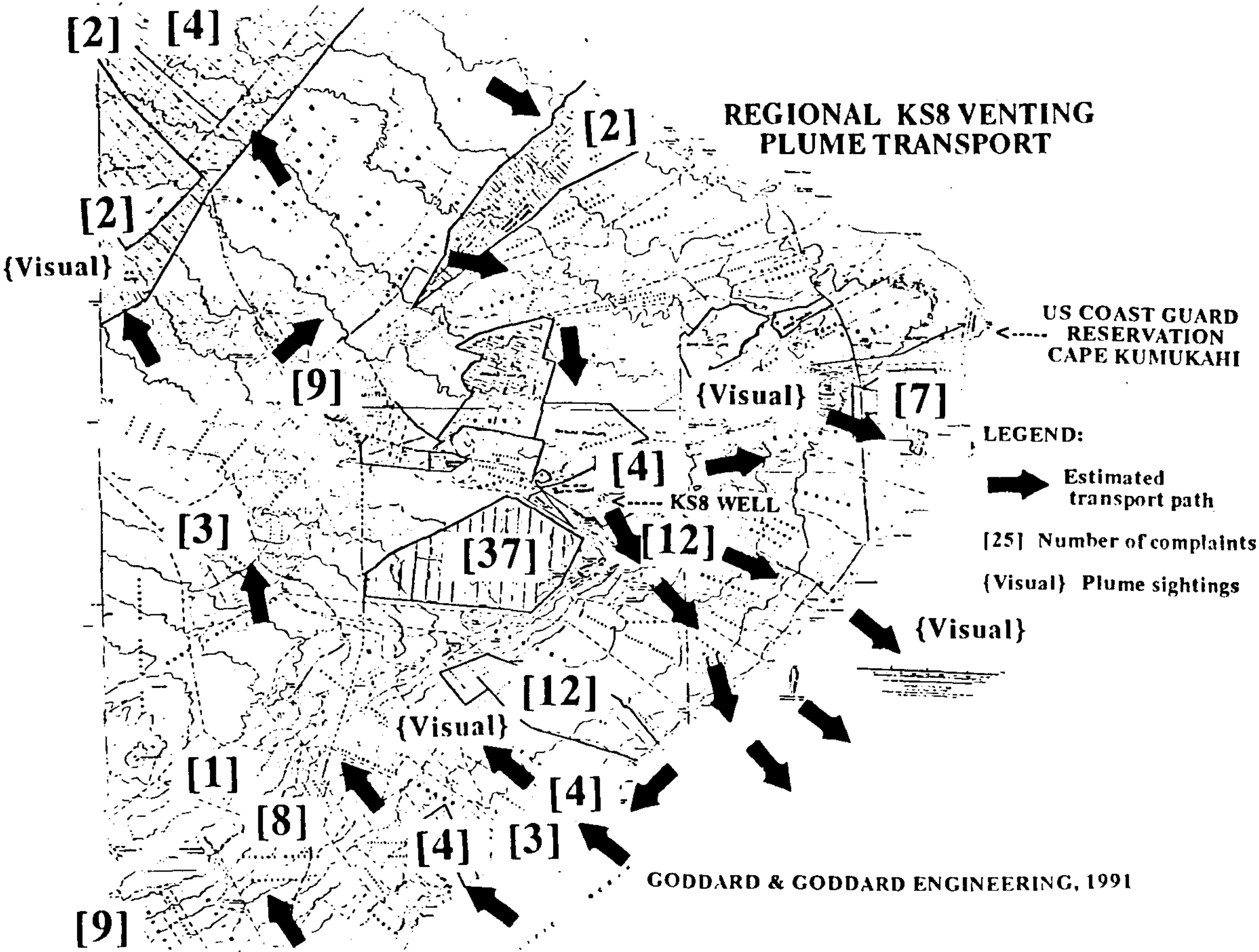

FIGURE 3-16 PGV KS8 WELL VENTING JUNE 12, 13 AND 14, 1991
REGIONAL PLUME TRANSPORT

3.2.1 Local Impact Assessments

The first complete comparison of measured spot readings and station monitoring began at 0100 hrs and is shown in Figure 3-3. From the 2319 hour event to 0200 hrs, no stationary monitoring site indicated an elevated reading. The out-of-plume influence area is clearly shown by the number of bracketed [0 ppb] points. The distance between the parts per million plume centerline and the outer isopleth value of 25 ppb is spanned in a few hundred feet. The values, such as the [280 ppb], [160 ppb] and [63 ppb] values, are all in agreement with the plume estimates. The [63 ppb] value which is outside of the plume positions perimeter is within the plume estimate if the plume centerline is moved to the outer estimated plume position boundary limit. The homes of impacted families are shown in the figures as squares.

The comparison between estimated and measured values of H2S are in substantial agreement for the ending times of 0400 hrs and 0500 hrs. At 0600 hrs, PGV increased venting horizontally at 254 deg. This is shown in Figure 3-6 as the line from the KS8 well site that widens the plume boundary to the west-southwest an estimated 1,200 ft. The effect of the horizontal venting is clearly indicated by the widening width of the area of high measured H2S concentrations.

Wind speed and atmospheric stability change the shape of the estimated plume concentrations. During daytime, as shown in Figure 3-8, dispersion lessens the distance at which high concentrations occur when compared to nighttime conditions such as Figure 3-4. At 1100 hours, as shown in Figure 3-8, the wind direction shifted the plume toward the Leilani Estates. The increased impact to the Estate continued through Figures 3-9, 3-10 and 3-11. At 2300 hours, the winds shifted the plume away from the Estates in a more southeasterly direction as shown in Figure 3-12.

From 0200 hours on June 14, 1991, shown in Figure 3-13, and 0500 hours shown in Figure 3-14, the transport is in a southeasterly direction. At 1200 hours, shown in Figure 3-15, the plume transport again impacts the edge of the Leilani Estate.

3.2.2 Regional Impact Assessment

The saturated steam-and-brine plume was seen at a considerable distance many miles away in part due to the saturated state of the atmosphere which did not evaporate the plume aerosols. In cooperation with the Kapoho Community Association and other concerned groups, health complaint reports were collected and analyzed for their chronological and positional information.

Appendix B contains a breakdown of the communities with health complaint reports, the number of complaints and reported symptoms, and a chronological and positional complaint-related assessment of the plume transport. This information is discussed further in Section 4 where the event impacts are related to referenced health effect symptoms.

The compiled health complaint data, in terms of numbers of complaints, is shown in the regional transport Figure 3-16. Four visual sightings are documented in the complaint files and these position the plume cloud in the areas shown in the figure by the bracketed word {Visual}. The plume was seen 2 miles (3 km) to northeast, 5 miles (8 km) to the southeast by fishermen who avoided penetrating the cloud by staying at sea, 4 miles (6 km) to the southwest when the plume cloud came ashore with the on-shore up-slope morning winds, and 5 miles (8 km) to the northwest where up-slope winds transported the plume cloud into Hawaiian Acres.

The plume transport estimates shown by the arrows on Figure 3-16 are based upon the site meteorological data, the Cape Kumukahi shore meteorological data, and the micrometeorology of local down-slope (katabatic) and up-slope (anabatic) winds analysis. The plume cloud over the two day venting period moved toward the sea during nighttime hours and then was transported inland during the morning hours. Later in the day, the trades again transported the plume seaward. The circular diurnal motion transported the noxious gases, aerosols and particulates over a considerable area as shown in Figure 3-16. The health complaints data chronological and positional data support the transport path estimate shown in Figure 3-16 and as shown in the transport map in Appendix B.

Using the low wind speeds which occurred at 0200 and 0500 hours on June 14, 1991, a capping ground based temperature inversion at 328 ft (100 m) and the 3.88 mph (1.73 mps) measured wind speed, results in the estimated H2S air quality impact, above ambient, listed in Table 3-1.

The ramifications of the health related H2S effects of such exposures as listed in Table 3-1 are discussed in Section 4. The values in Table 3-1 are hourly averages. Three to ten minute peaks would be expected to be 1.6 times higher. For example, at 10 miles the peak level, at a 68% confidence level (mean plus 1 standard deviation) is (58.5 ppb + 23.4 ppb) x 1.6 = 131 ppb (183 ug/m3) H2S concentration above ambient. Impacts for other air toxics listed in Table 1-1, are directly proportional to their respective emissions rates.

TABLE 3-1

KS8 VENTING HIGHEST HOURLY AIR QUALITY IMPACT SUMMARY

General Inversion Dispersion Estimate For Slightly Stable
Pasquil Class E, ground based capping temperature inversion at
328 ft (100m), wind speed 3.88 mph (1.73 mps) which occurred on
June 14, 1991 at 0200 hrs and 0500 hrs.

Receptor Down Wind along transport path		CONCENTRATION ABOVE AMBIENT			
miles	kilometers	ug/m3	±	ppbv	±
1.0	1.6	734.9	256.1	528.7	184.2
2.0	3.2	289.5	100.4	206.8	71.7
3.0	4.8	201.9	80.8	143.7	57.5
4.0	6.5	162.4	65.0	114.4	45.8
5.0	8.1	137.2	54.9	96.6	38.7
6.0	9.7	119.5	47.8	84.8	33.9
7.0	11	106.4	42.6	75.7	30.3
8.0	13	96.2	38.5	68.7	27.5
9.0	15	88.0	35.2	63.1	25.2
10	16	81.2	32.5	58.5	23.4

Note:

Conversion from ug/m3 corrected for temperature and elevation;
The ± uncertainty denotes a 68% probability confidence level;
Values estimated at the plume centerline at 5 ft (1.5 m) height.

GODDARD & GODDARD ENGINEERING - ENVIRONMENTAL STUDIES, 1991

4.0 PUBLIC HEALTH EFFECTS

The environmental health effects of air pollutants are determined by the concentration to which the individual is exposed, individual susceptibility, the mixture of compounds and the duration of exposure.

- **Concentration.** The health effects of various concentrations of air pollutants are summarized in Tables 4-1 and 4-3. A more detailed discussion is given in Goddard (1984).

- **Individual Susceptibility.** Different age groups within the general population are more susceptible than others to the effects of the various emissions. Those with enhanced sensitivity to hydrogen sulfide poisoning include individuals with eye or respiratory tract problems, or anemia, those who have consumed alcohol within 24 hours of exposure, those who have psychiatric problems, infants, and those who have been previously exposed to hydrogen sulfide (IIEQ, 1974). The evidence of "enhanced sensitivity" is not conclusive.

The level and frequency of odor which would annoy individuals varies, and it is frequently not only the concentration level but also the change in concentration which arouses public intolerance (Leonardos et al., 1969). Layton et al. (1981) conclude that an ambient level of 0.03 ppm, hourly average, -- six times higher than the median instantaneous threshold value -- would result in odor nuisance problems, partly because elevated excursions (10 to 15 minutes) during an hour could be particularly annoying.

- **The mixture of pollutants.** The environmental effects of air pollutants listed in Table 4-1 are for individual pollutants. However, they may be synergistic or antagonistic as well as independent (Kestin et al., 1980).

- **The effect of duration of exposure** is related to the other three factors - the concentration, the individual susceptibility and the mixture of pollutants.

The national and state air quality standards are established to reduce or prevent these effects. These standards are based on epidemiological and toxicological studies and assume the existence of threshold levels of concentration below which there are no adverse effects on the general population. The difference between the air quality standard and the threshold level may be defined as a "margin of safety". The larger the margin of safety, the greater the fraction of the population protected by the air quality standard (Case et al., 1977).

Concentrations of hydrogen sulfide below the suggested value of 24 ppb discussed in Section 2 may still constitute a "public nuisance" defined by various Civil Codes:

> "one which affects, at the same time an entire community, or neighborhood or a considerable number of persons, although the extent of the annoyance or damage inflicted on individuals may be unequal".

The health effects of air pollutants often found in geothermal resources and developments are listed in Table 4-1. Occupational Health and Safety Administration (OSHA) health standards are given in Table 4-2 and are designed to protect the working population. The health effects of hydrogen sulfide are listed with references in Table 4-3. The OSHA standards are for a work force and since this excludes the most susceptible portion of the population, these standards when applied to the general population are reduced. The California Department of Health Services (CDHS) interprets Proposition 65 air-borne toxic trigger points concentrations as being 1% to 0.1% of the OSHA TLV values. This is to ensure protection of sensitive individuals which include the young, old and infirm. Recent Air Toxics legislation implementation has been interpreted by CDHS as using the OSHA values divided by 420, as described previously, when applied to the general public (CARB/CDHS 1990).

TABLE 4-1

HEALTH EFFECTS OF AIR POLLUTANTS FROM GEOTHERMAL DEVELOPMENT

Ammonia (NH_3). Odor threshold: 5.2 ppm (Amoore et al., 1983). Eye irritation: 5 ppm (NIOSH, 1974), 72 ppm (Industrial Bio-Test Labs, 1973). Inhalation irritation: 20 ppm (EPA, 1977). Nasal irritation: 32 ppm; chest irritation: 134 ppm (Industrial Bio-Test Labs, 1973). Increased morbidity and mortality: 70-105 ppm (Bittersohl, 1971). Pulmonary edema: 1,700-4,500 mg/m^3. Low levels: no permanent adverse health effects (EPA, 1977). Leaf damage in sensitive plants: 3-12 ppm for 4 hours (Benedict et al., 1955).

Ammonium Bisulfide (NH_4HS). Penetrates the skin more rapidly than hydrogen sulfide. Since it is an inherently unstable solid, it readily dissociates back to hydrogen sulfide and ammonia gases.

Ammonium Sulfate $(NH_4)_2SO_4$. Toxic to plants (Malloch et al., 1979; Sharp, 1976).

Arsenic (As). All forms of arsenic are toxic at various levels; some are potentially carcinogenic (Lee and Fraumeni, 1969; Tseng et al., 1968; Lander, 1975; NIOSH, 1975). Arsenic compounds are known to be corrosive to skin and are identified as a carcinogen. Brief contact has no effect, but prolonged contact can cause skin irritation, with mucous membranes the more sensitive to irritation (CAL/OSHA, 1983). Fluids containing arsenic levels of 5 mg/l (ppm) are considered toxic by the State of California (Department of Health Services, 1984). Odor threshold: 0.50 ppm (Amoore et al., 1983). The fatal dose is 70-180 mg/m^3.

Boron(B). Data related to humans are limited. Several forms of boron are irritants to skin and mucous membranes. Ingestion of 15-20 gm of borax caused acute poisoning. Boron particulate fallout damages plants (Malloch et al., 1979; Sharp, 1976). Exact levels are not given but, for comparison, irrigation water with 10-100 ppm boron content is toxic to plants (Eaton, 1935).

Carbon Dioxide (CO_2). 2% in air can stimulate human respiration. Not considered hazardous when adequate oxygen present (Gennis, 1978). Odor threshold: 74,000 ppm (Amoore et al., 1983).

Chlorides. Not expected to produce adverse health effects (OXY, 1981).

Ethane (CH_3CH_3). A simple asphyxiant. No hazard known in well-ventilated environments (Gennis, 1978). Odor threshold: 120,000 ppm (Amoore et al., 1983).

Hydrogen (H_2). A simple asphyxiant. No hazard known in well-ventilated environments (Gennis, 1978).

Hydrogen Sulfide (H_2S). Odor threshold: 0.0081 (Amoore et al., 1983). Increased neurasthenic effects (fatigue, dizziness, nausea) with long term exposure: above 0.1 ppm. Eye irritation threshold: 10 ppm. Inhalation irritation threshold: 50-100 ppm. Sense of smell stops: 150 ppm. Fatal: 700 ppm. Damage to sensitive plants: more than 0.30 ppm (Thompson, 1976); 40 ppm for five hours (McCallan et al., 1936).

TABLE 4-1 (Continued)

HEALTH EFFECTS OF AIR POLLUTANTS FROM GEOTHERMAL DEVELOPMENT

Mercury (Hg). The human lung absorbs 75-85% at concentrations of 50-350 mg/m^3, almost completely at lower concentrations (Kudsk, 1966). Inhalation produces many adverse effects. Mercury may also be absorbed through the skin or by ingestion. Elimination is slow, resulting in long-term effects which are only partially reversible. Children appear to be especially susceptible (Britt et al., 1976). Methylmercury (CH_3Hg+), the most toxic form, may cause growth deformities (Walton et al., 1978). Inhalation of 100 μg/m^3 can cause chronic mercury poisoning, of 1,200-8,500 μg/m^3 can cause acute poisoning. Occupational exposure to 10-30 μg/m^3 of elemental mercury may cause slight anemia, hypothyroidism and increased excitability. Prolonged exposure may cause neurologic disorders (Walton et al., 1978). Mercury is toxic to plants at levels in the parts per billion range over several days (Jacobson et al., 1970). Over 10 ppm dry weight in plant tissue is toxic.

Methane (CH_4). Odorless. Not known to induce ill effects even at high concentrations in ambient air.

Nitrogen (N_2). No known hazard from its increased presence in ambient air.

Radon-222 (^{222}Rn). Adverse health effects, including lung cancer, may result from inhalation of Radon-222 and its short-lived, alpha-particle emitting daughters (BEIR, 1972). There is at present no known level of exposure to radiation below which no biological damage occurs (Kestin et al., 1980).

Sulfur Dioxide (SO_2). Annual concentrations of 0.05 ppm (130 μg/m^3) led to increased frequency of respiratory illness. The threshold for increased chronic bronchitis in adults and increased acute lower respiratory disease in children is 95-200 μg/m^3 (EPA, 1974; 1975). Hospital admissions with respiratory illness increased when 24 hour sulfur dioxide concentrations were 0.12-0.19 ppm (Finklea, 1973). Odor threshold: 1.1 ppm (Amoore et al., 1983). Irritation threshold: more than 3 ppm (Case et al., 1977). 1-10 ppm (2,600-26,000 μg/m^3) increased airway resistance in humans and other animals. More than 400 ppm caused death. 0.3 ppm for 8 hours is toxic to plants (Gauch et al., 1954).

Sulfates. Taste/odor threshold: 700 μg/m^3. Irritation Threshold: 350-2,000 μg/m^3. 10-3,000 μg/m^3 can cause illness (Case et al., 1977; Layton et al., 1981). Brief exposure to 700-5,000 μg/m^3 sulfuric acid mist (H_2SO_4) resulted in increased airway resistance.

Suspended Particulate Matter. The health effects of suspended particulate matter depend on the particle size and chemical composition. "No effects" threshold: 100 μg/m^3 (Case et al., 1977). Morbidity threshold: 300-375 μg/m^3 (DHEW, 1970). Mortality threshold: 200-750 μg/m^3. Particles larger than 0.5-2 μm diameter are usually trapped in the upper respiratory system and cleared in a few minutes. Smaller particles may remain in the body for months or years (Case et al., 1977).

TABLE 4-2
OSHA OCCUPATIONAL STANDARDS FOR AIRBORNE CONTAMINANTS

SUBSTANCE	PEL (1) ppm	mg/m3	EXCURSION LIMIT (2)	EXCURSION DURATION (3) ppm	CEILING LIMIT (4)	MAXIMUM CONCENTRATION (5)
AMMONIA	25	18				37.5 ppm
ARSENIC and inorganic arsenic compounds	-	0.01				.03 mg/m3
ARSENIC, organic compounds, as As	-	0.2				0.6 mg/m3
ARSINE	0.05	0.2				0.15 ppm
BENZENE	10	30	25	8 hrs/ 10 min	50 ppm	
BORON OXIDE	-	10				20 mg/m3
BORATES Anhydrous and pentahydrate	-	1				3 mg/m3
decahydrate	-	5				10 mg/m3
CARBON DIOXIDE	5,000	9,000				7,500 ppm
ETHANE	(limiting factor is available oxygen)					
HYDROGEN SULFIDE	10	15	20	8 hrs/ 10 min	50 ppm	
MERCURY						
alkyls as Hg	0.001	0.01			0.04 mg/m3	
all forms except alkyls as Hg vapor	-	0.05			0.1 mg/m3	
aryl and inorganic compounds	-	0.1			0.2 mg/m3	
DUST	10 (5 Respirable)					
SULPHUR DIOXIDE	5	13				10 ppm

RADON-222(1) 3,000 pCi/m^3 (3.0 pCi/l) uncontrolled areas
100,000 pCi/m^3 (100 pCi/l) controlled areas

SOURCE: Summarized from OSHA Publication 5155

EXPLANATION OF TABLE 4-2

(1) PEL (Permissible Exposure Limit) - the maximum permitted 8-hour time weighted average concentration of an airborne contaminant. The PEL reflects the conditions and amounts of a substance to which most workers can have a daily exposure during a 40 hour work week for a working lifetime without suffering ill effects. The PEL may be established to protect against illness, disease, irritation, narcosis, nuisance or other forms of stress. PELs apply only to occupational settings and occupational exposures.

(2) Excursion Limit - the maximum concentration of an airborne contaminant to which an employee may be exposed without regard to duration provided the 8-hour time weighted average concentration does not exceed the permissible exposure limit.

(3) Excursion Duration - the maximum time period permitted for an exposure above the excursion limit but not exceeding the ceiling limit.

(4) Ceiling Limit - The maximum concentration of an airborne contaminant to which an employee may be exposed at any time.

(5) Maximum Concentration - where the ceiling limit is not specified, the maximum concentration to prevent adverse health effects is calculated as in 5155 (c) (2) (B).

(6) In the absence of information to the contrary, the adverse health effects of exposure to two or more toxic materials during the workday shall be considered additive.

TABLE 4-3

HEALTH EFFECTS OF HYDROGEN SULFIDE ON HUMANS

Concentration ppm	mg/m^3	Effects	Reference
0.020 to 0.039	0.028 to 0.055	Harmful long term effects on adults and the growth of young organisms especially infants.	Glebova c.b. Loginova (1957)
0.070	0.098	Affects light sensitivity of the eye.	Tuan c.b. Meyer (1978)
0.086	0.12	Increased incidence of mental depression, dizziness and blurred vision.	Schieler c.b. IIEQ (1974)
0.32	0.45	Increased incidence of nausea, loss of sleep shortness of breath and headaches following chronic exposure.	U.S. Public Health (1964) c.b. IIEQ (1974)
0.71 to 7.1	1.0 to 10	Increased incidence of decreased corneal reflex (convergence and divergence) after chronic exposure.	Rubin and Arieff (1945), Lewey (1938) c.b. IIEQ (1974)
7.1 to 50	10 to 70	Irritation of conjunctiva, fatigue, loss of appetite and insomnia after chronic exposure.	Barthelmy (1938) Masure (1950), Ahlborg (1952), c.b. IIEQ (1974)
10 to 15	14 to 21	Conjunctival and corneal inflammation, "threshold of irritation" according to Gurinov.	Butrin, Arkhangels'kii c.b. Gurinov (1952)
50 to 107	70 to 150	Irritation to eyes, i.e., conjunctivitis and keratitis with photophobia, after several hours of exposure.	Deveze (1957), Beasley (1963), Nyman (1954), c.b. IIEQ (1974)
50 to 100	70 to 140	Sub-acute poisoning, mild conjunctivitis and mild respiratory tract irritation after one hour exposure.	Yant (1930) c.b. Moyer (1978)
100	140	Slight symptoms may appear after several hours.	Fairhall (1957) c.b. Moyer (1978)

TABLE 4-3 (Continued)

HEALTH EFFECTS OF HYDROGEN SULFIDE ON HUMANS

Concentration ppm	mg/m^3	Effects	Reference
100	140	Paralyzes the olfactory nerve.	Poda (1966)
70 to 150	98 to 210	Slight symptoms after several hours exposure.	Henderson & Haggard (1943) c.b. Moyer
107 to 210	150 TO 300	Slight systemic symptoms after many hours of exposure; possible hemorrhage and death within 48 hours.	Henderson & Haggard (1943), Haggard (1925), c.b. IIEQ (1974)
150	210	Olfactory paralysis almost immediately.	Evans (1967) c.b. DWR (1978)
160	225	Olfactory paralysis.	IIEQ (1974)
160	225	Irritation to respiratory tract and eyes within 1 hour, becoming more severe with longer exposure, i.e., conjunctivitis, bronchitis and keratitis with photophobia.	Nyman (1954), Ahlborg (1952), Mitchell and Yant (1925), Carson (1963) c.b. IIEQ (1974), DWR (19
170 to 300	238 to 420	Maximum concentration that can be inhaled for one hour without serious consequences.	Henderson & Haggard (1943) c.b. Moyer (1978)
200 to 300	280 to 420	Sub-acute poisoning, marked conjunctivitis and respiratory tract irritation after one hour exposure.	Yant(1930) c.b. Moyer (1978)
210 to 360	300 to 500	Nervous system depression.	Ahlborg (1952) c.b. IIEQ (1974)
210 to 360	300 to 500	Slight systemic symptoms within 4 to 8 hours, hemorrhage and death within 48 hours.	Henderson & Haggard (1943), Haggard (1925), Mitchell & Yant (1925) c.b., IIEQ (1974)

TABLE 4-3 (Continued)

HEALTH EFFECTS OF HYDROGEN SULFIDE ON HUMANS

Concentration ppm	Concentration mg/m^3	Effects	Reference
210 to 360	300 to 500	Irritation to respiratory tract, eyes and loss of smell within 30 minutes becoming more severe with longer exposure; photophobia and dypsnea (difficult breathing) within 4 hours, possible pulmonary edema.	Haggard (1925), Breysse (1961), Mitchell & Yant (1925), c.b. IIEQ (1974)
360 to 500	500 to 700	Slight systemic symptoms within 4 hours, hemorrhage and death within 8 hours.	Henderson & Haggard (1943), Mitchell & Yant (1925) c.b. IIEQ (1974)
360 to 500	500 to 700	Irritation to respiratory tract and eyes and loss of sense of smell within 30 minutes; dypsnea, conjunctivitis and keratitis with photophobia within 1 hour. Possible pulmonary edema.	Haggard (1925), Breysse (1961), Mitchell & Yant (1925) c.b., IIEQ (1974)
400 to 700	560 to 1,000	Dangerous exposure after 30 to 60 minutes exposure.	Henderson & Haggard (1943) c.b., Moyer (1978)
600	840	Fatal after 30 minutes.	Henderson & Haggard (1943) c.b. Moyer (1978)
500 to 640	700 to 900	Slight systemic symptoms within 1 hour, i.e. headache, dizziness; unconsciousness and death within 4 to 8 hours.	Henderson & Haggard (1943), Mitchell & Yant (1925) c.b. IIEQ (1974)
500 to 640	700 to 900	Serious irritation to respiratory tract and eyes within 30 minutes, i.e., coughing, bronchitis, pharyngitis, dypsnea, possible pulmonary edema, photophobia, conjunctivitis and keratitis.	Haggard (1925), Breysse (1961), Mitchell & Yant (1925), IIEQ (1974)
500 to 700	700 to 1,000	Sub-acute poisoning, dangerous in 30 minutes to 1 hour.	Yant (1930) c.b. Moyer (1978)

TABLE 4-3 (Continued)

HEALTH EFFECTS OF HYDROGEN SULFIDE ON HUMANS

Concentration ppm	mg/m^3	Effects	Reference
640 to 1,000	900 to 1,400	Systemic effects predominate over local irritation effects. Systemic symptoms within 30 minutes, collapse, asphyxia and death within 1 hour.	Henderson & Haggard (1943), Mitchell & Yant (1925), Simpson & Simpson (1971) c.b. IIEQ (1974)
710 to 1,500	1,000 to 2,100	Lethal to man.	Gurinov (1952)
700 to 1,000	1,000 to 1,400	Possible acute poisoning, rapid unconsciousness, death.	Yant (1930) c.b. Moyer (1978)
700 to 900	1,000 to 1,300	Rapidly produces unconsciousness, cessation of respiration and death.	Poda (1966)
1,000	1,400	Rapidly fatal.	Fairhall (1957) c.b., Moyer (1978)
1,000 to 2,000	1,400 to 2,800	Acute poisoning, rapid unconsciousness, death in a few minutes.	Yant (1930) c.b. Moyer (1978)
1,000 to 2,000	1,400 to 2,800	Systemic effects predominate over local irritant effects. Immediate systemic symptoms, i.e., stimulation of respiratory (hypernea), followed by respiration inactivity (apnea) collapse, asphyxia and death within 30 minutes.	Patty (1963) c.b. Haggard (1925) Haggard & Henderson (1922) c.b. IIEQ (1974)
2,000 to above	2,800 to above	Systemic effects predominate over local irritant effects. Paralysis of respiratory center; immediate death.	Haggard (1925) Yant (1930) c.b. IIEQ (1974)

4.1 COMMUNITY HEALTH IMPACT ASSESSMENT

Health complaints have been and are in the process of being collected by several individuals, concerned citizen groups and by State and County Agencies. A compilation of presently available health complaints has been provided through the work of Mrs. Hedtke, Secretary of the Kapoho Community Association and through cooperation with the Big Island Rain Forest Action Group, Colleen Mandals, and many others. A summary of the results shown by area impacted in Figure 3-16 is listed in Table 4-4 which includes the tabulation of 123 health complaints.

The compilation is included in Appendix B and lists 26 symptoms tabulated for 17 communities surrounding the PGV site. The odor of sulfur, eye irritations, and trouble breathing were experienced by every community included in the survey. Of the 123 respondents, 8 required medical care, 87 (70%) heard the venting noise of which 85 found the noise irritating (69%), 97 smelled sulfur (79%), 74 (60%) experienced eye irritation, 77 (63%) experienced throat irritation, 18 (15%) experienced trouble breathing, 24 (20%) experienced coughing and wheezing, and 24 (20%) experienced nose irritation.

The referenced start of eye effects in Table 4-3 occurs at a level of 70 ppb H2S, with dizziness and depression at 86 ppb, followed by nausea and loss of sleep at 320 ppb. The onset of conjunctival and corneal inflammation, which is the basis of the OSHA 8 hour worker standard occurs at a referenced 10 ppm (10,000 ppb).

Exposed individuals and families within a one mile radius of the KS8 well venting were estimated to have been impacted at H2S levels indicated in Figures 3-3 through Figures 3-15. Concentrations of H2S in the first mile (1.6 km) from the venting site are estimated to have exceeded 500 ppb with centerline peaks above 2,000 ppb (2 ppm). The initial steam and brine cloud is estimated to have concentrations of 900 ppm. Emissions that were restricted by the drill rig decking or were expansion cooled, are estimated to have produced periods where peaks could have exceed 36 ppm at 528 ft (160 m) and 1.36 ppm at 1.0 mile (1.6 km).

Individuals down wind are estimated to have been exposed to concentrations, above ambient, as listed in Table 3-1. Peak values, 3 to 10 minute average, at a 68% confidence level are estimated at as far as 10 miles (16 km) to exceed 131 ppb with an hourly average concentration of 81.9 ppb at the plume centerline.

The health complaint symptoms that are compiled in Table 4-4 are referenced at levels starting at 20 ppb in Table 4-3. Severe eye inflammation at 10 ppm are estimated to occur for those individuals or families that were exposed to the plume within 1,000 ft (348 m) of the KS8 well venting site.

A previous health study conducted in 1987 of residents in the Puna area, found that chronic respiratory conditions including bronchitis/emphysema, asthma, hayfever, sinusitis and other respiratory system diseases rates were higher than reported in Hawaii County or statewide in 1983 (Anderson, 1987). Individuals with such respiratory illnesses are more sensitive to adverse health effects of gaseous and particulate pollutants.

Other toxic constituents of the steam and brine cloud are listed in Table 1-1. The Total Dissolved Solids estimated emissions listed in Table 1-1 are estimated to result in high concentration impacts of aerosols and particulates in the steam and brine cloud. For instance the 13.6 lb/hr of lead results in an estimated hourly average exposure at 10 miles along the plume centerline of 8.59 ug/m3 above ambient. While the exposure time was short for individuals and no long term adverse health effects are foreseen, the high levels of gaseous air toxics concentrations added to other heavy metals, aerosol, particulates and H2S are estimated to have given rise to the reported adverse health complaints.

TABLE 4-4

KS8 WELL VENTING COMMUNITY HEALTH COMPLAINTS

Name	Distance miles	Direction	Health Complaint Numbers
Puu Honuaula	0.6	East	4
Lanipuna	3	South	12
Pohoiki Bay Estates, Leilani	1	Southwest	37
Opihikao Homesteads	1	Southwest	12
Puna Palisades	5	South	3
Kehena	4	South	4
Kalapana Seaview Estates	10	Southwest	9
Black Sands Subdivision	6	Southwest	8
Upper Kaimu Homesteads	7	Southwest	1
Kamaili Homesteads	4	South	4
Kaohe	5	South	3
Ainaloa, Orchidland	9	Northwest	2
Hawaii Acres	8	Northwest	2
Hawaiian Paradise Park	9	Northwest	4
Hawaiian Beaches, Hawaiian Shores	5	Northwest	2
Pahoa, Nanawale	4	Northwest	9
Kapoho	4	Northeast	7
	Total Health Complaints		123

Source:
Appendix B
Big Island Rain Forest Action Group
Colleen Mandals, Pahoa Natural Foods
Kapoho Community Association

5.0 SUMMARY AND CONCLUSIONS

The following findings are in accord with those in the Element III Part I report. The focus here is on the air quality and adverse health effects of the event.

The air quality impacts of the KS8 June 12, 13 and 14, 1991 blow-out resulted in high emission levels of H2S and other air toxics from the project area. Individuals and families near and surrounding the site for several miles experienced periods where health complaints resulted from exposures to the released air toxics in the form of gases, aerosols and particulates.

Local values of H2S, measured and estimated, have been shown to be in substantial agreement within 1.0 mile (1.6 km) of the release site. The zone of high impact was increased by PGV horizontal venting.

Regional estimated plume transport to 10 miles has been shown to compare to regional coastal wind measurements, to land and sea based local wind generation, to local plume cloud sightings, and to the observed chronology and position of health complaints. Estimates of 10 mile impacts of H2S within the plume cloud centerline are high enough to yield observed symptoms at concentrations as referenced in the report.

A "worst case" impact event with the same emissions as the KS8 uncontrolled venting where winds were near calm or at 1.0 mph (0.4 mps) would have increased impacts an estimated 4 to 10 times. Under worst case conditions, the distance to where health complaints were reported would be extended several fold.

It appears that the event was due to lack of preparedness and mismanagement of techniques which could have prevented unabated H2S releases. It is our opinion that the permittee has apparently violated air H2S emissions limits and H2S air quality impact limits, as well as other ambient air quality standards for other air toxics, as well as noise level limits and noise level control average criteria permit requirements.

It appears the permittee has failed to use and/or manage the use of Best Available Control Technology in abating the air emissions and the noise levels. It appears the permittee has used equipment not described in the Authority to Construct which may have added to the air emissions and noise levels during the event.

The DOH air quality and noise permit conditions were stringent enough, if they had been followed by PGV, to protect the health and safety of the surrounding citizens. Unfortunately, only a few foresaw the likelihood of such a high concentration of air toxics emissions and such a prolonged venting period.

6.0 RECOMMENDATIONS

The following recommendations are in accord with those in the Element III Part I report. The focus here is on avoiding future emission exceeds and in documenting, in the surrounding communities, possible future air quality impacts and adverse health effects. It is recommended that PGV pay for any additional expense involved in implementing the following measures:

1. Emissions limits for H2S be vigorously and rigidly enforced by DOH personnel.

    o. Implement emissions limits with frequent field inspections by DOH personnel on an unannounced basis to verify compliance.

    o. Emission rate measuring procedures, equipment and a maintained database should be implemented which quantify the emission rates and log the emissions data.

    o. Geochemical analysis of the resources should be verified frequently by independent laboratory analysis.

    o. New resources should be immediately geochemically analyzed at a frequency at which minimal changes between samples is observed.

    o. Developed resources should be geochemically analyzed on a quarterly basis with more frequent analyses if a 10% change is observed between analyses.

2. A Puna Air Monitoring Program (PAMP) be formed managed by DOH with participation by the developer, the local agencies, State agencies, local concerned organizations and local concerned citizens.

    o The PAMP committee should be responsible for managing an independent agency or contractor management of the air and noise monitoring program.

    o Costs of the program should be borne by the developer.

    o Monitoring sites should be unified under the PAMP program.

    o Sites should establish a uniform Quality Assurance program to standards established by the USEPA.

    o The committee should be responsible for Quality Assurance of all data with reports unified under the PAMP program.

    o The committee should establish routine third party station audits which should be performed by qualified personnel.

- o Equipment operated in the PAMP program should be as uniform as possible with uniform data logger formats, and report structures, and should have data modem-accessible for Operational Management of Air Resources (OMAR) type functions (see Appendix C).

- o The committee should coordinate the availability of data through a central computer system linked by telephone and/or telemetry so the emergency response will be automatic 24 hours a day for each station.

- o The committee should coordinate with a limited number of external users to the data archiving central OMAR type computer so that non quality assured data is made available to the public.

- o The committee should oversee the recommended equipment installation and, before further geothermal exploration occurs in the area, conduct meteorological investigations of the proposed new explorations area to clearly establish the "worst case" micrometeorological relationship between the area's future geothermal emissions and local and regional impacts.

3. Modify station positions and install additional meteorological monitoring equipment and sites to further study the geothermal air pollution meteorology of the location and zone of impact as shown in Figure 6-1. Each of the station changes should be done sequentially starting with the present stations farthest from the PGV site.

   A. PGV Site specific measurement stations - these stations and locations are designed to define the micrometeorology, the conditions aloft, and possibly record and give alarm on elevated H2S emission events near PGV planned and upset venting sites.

      - o To better define the atmospheric stability and winds near the surface and aloft near the PGV site, it is recommended that a 40 meter tower be installed at a convenient location near the present Irvine station. The tower should be equipped with wind speed, wind direction, temperature and humidity at 40 meters, 20 meters and at 10 meters so that atmospheric stability, and the magnitude and gradient of temperature, wind speed and humidity may be obtained. The tower should be equipped with a data logger and linked through telephone or telemetry to the central OMAR type computer.

      - o Discontinue meteorological monitoring at the SW station, since the station is close to the Irvine station, while maintaining the air quality monitoring. Equip the station with the ability to measure H2S in the lower ppb range and with a second instrument or autoranging measure H2S in the mid to high ppm range. Link the station into the central OMAR type computer system by telemetry or telephone.

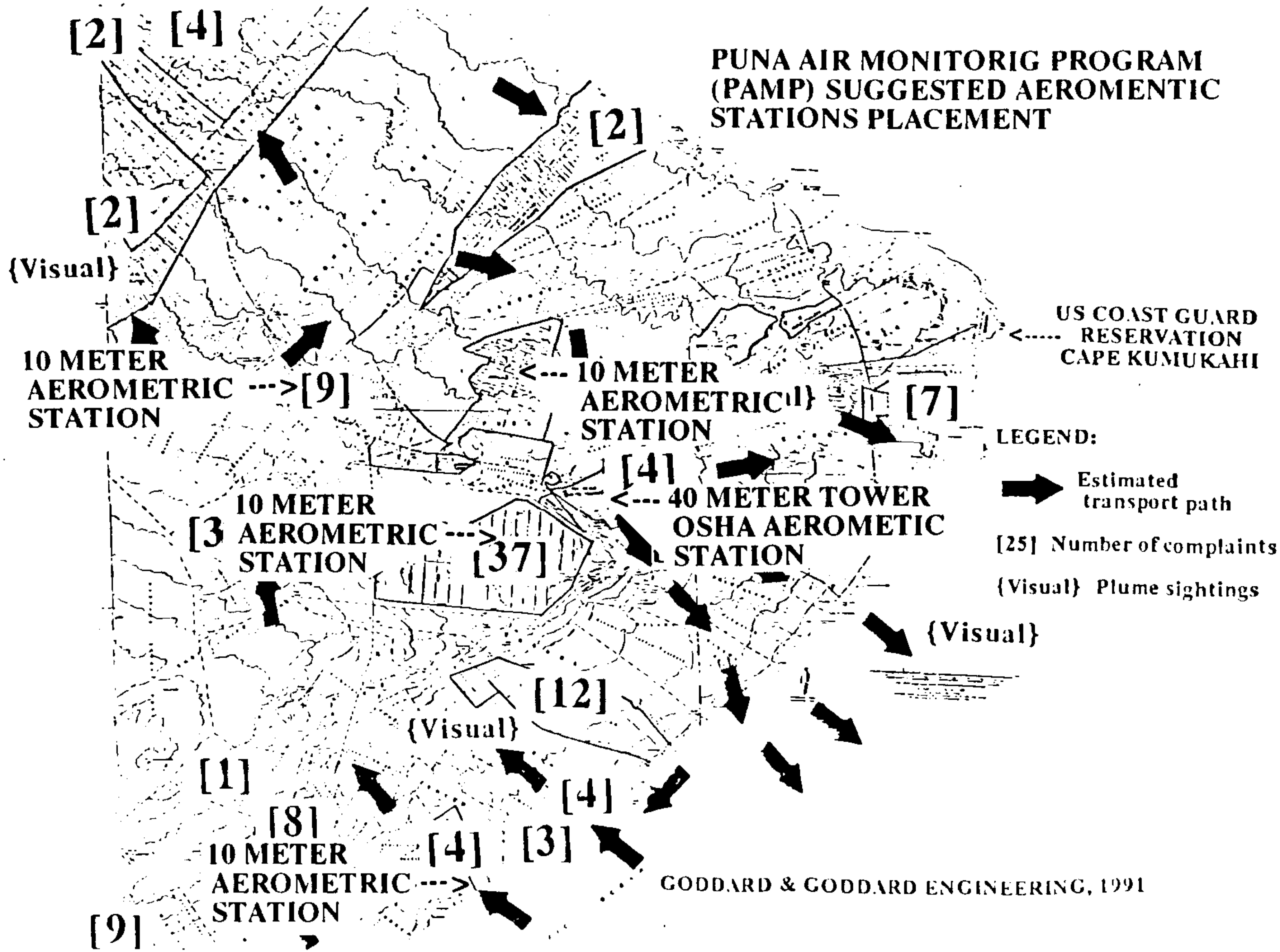

FIGURE 6-1 SUGGESTED PAMP AEROMETIC MONITORING STATIONS PLACEMENT

B. Surrounding Community Aerometric Stations - these stations and locations are designed to gain a more regional understanding of the micrometeorological conditions and provide air quality surveillance and emergency community warning.

- Relocate the Wade station within the interior of the Leilani Estates. Equip the station with H2S monitoring in the ppb range, and 10 meter wind speed, wind direction including sigma, temperature, humidity and precipitation. Link the station into the central OMAR type computer system by telemetry or telephone.

- Relocate the Wood site within the Pahoa community. Equip the station with H2S monitoring in the ppb range, and 10 meter wind speed, wind direction including sigma, temperature, humidity and precipitation. Link the station into the central OMAR type computer system by telemetry or telephone.

- Relocate the Alvarez station within the Kaniahiku community. Equip the station with H2S monitoring in the ppb range, and 10 meter wind speed, wind direction including sigma, temperature, humidity and precipitation. Link the station into the central OMAR type computer system by telemetry or telephone.

- Relocate the SE station within the Kehena Beach Subdivision so that coastal conditions are more adequately monitored. Equip the station with H2S monitoring in the ppb range, and 10 meter wind speed, wind direction including sigma, temperature, humidity and precipitation. Link the station into the central OMAR type computer system by telemetry or telephone.

- A uniform method of sampling precipitation at each PAMP station should be initiated with regular chemical assessments of the constituents including heavy metals until the background conditions are well understood;

- The PAMP committee should oversee development of a uniform monitoring program of known PGV geothermal air toxics which through "worst case" dispersion analysis estimation surpass a health significance level of 1:100,000 in any populated area.

4. PAMP manage local and regional air transport studies in future geothermal explorations areas before initiation of geothermal development.

   - A series of "worst case" poor air dispersion meteorological condition tracer studies should be initiated in new areas of geothermal explorations. If the new area is a step-out from the PGV location, the study should include releases at the PGV power plant site rock muffler, simulating estimated steam plume rise, and at possible normal operations and upset conditions venting points in the well field. Multiple tracer sampling sites should be situated in communities which may be impacted in addition to mobile and aircraft grab sampling. The temperature and wind structure aloft should be monitored during the tests.

   - Each tracer study should be paid for by the developer with adequate funds for the PAMP committee to hire a qualified firm to conduct the tests. The firm should statistically assess the frequency of "worst case" that the particular test represents.

   - The PAMP committee should be responsible for quality assurance of the tracer studies, documenting each test and findings and publishing sufficient volumes of the test description and results so that the results will be available for developers, engineers and environmental scientists.

5. The PAMP committee should quality assure monitoring data, document all quality assurance procedures and publish sufficient volumes of the monitoring documents that developers, engineers and environmental scientists have access to the documents.

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APPENDIX A

MICROMETEOROLOGICAL AIR DISPERSION ASSESSMENT METHODOLOGY (MADAM)

Geothermal Resources Council TRANSACTIONS Vol. 11 October 1987

MICROMETEOROLOGICAL AIR DISPERSION ASSESSMENT METHODOLOGY (MADAM) A GEOTHERMAL AIR QUALITY IMPACT ASSESSMENT TOOLBOX AVAILABLE AS SHAREWARE

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ABSTRACT

The newly completed Micrometeorlogical Air Dispersion Assessment Methodology (MADAM) year long project was funded by the California Energy Commission through the Geothermal Grant Program and was managed by the Lake County Air Quality Management District. The purpose of the project was to develop a verified methodology for geothermal air quality impact assessment for use by regulators, industry and interested groups. The developed and verified methodology reduces the time and effort normally expended in determining geothermal air quality impacts through use of a Personal Computer based program. MADAM is available for interested users cost free as share- ware ($45 registers users for new version announcements) Application, user and reference manuals and assistance are available from GODDARD & GODDARD ENGINEERING. Versions are available for CP/M, PC/MSDOC, Apple IIe (with Applied Engineering Z80 board), and Macintosh PC computers.

PROJECT GOAL

The primary goal of the Micrometeorological Air Dispersion Assessment Methodology (MADAM) project was to develop and document a verified methodology that could be used by the Lake County Air Quality Management District (LCAQMD) staff to quickly, accurately and inexpensively estimate air dispersion pollutant concentrations occurring from a variety of geothermal emission sources in the mountainous Geysers Known Geothermal Resource Area (KGRA).

The developed air dispersion assessment methodology was required to have verified reliability, and be realistic and systematic in evaluating air quality impacts from nearby geothermal emission sources (within a few miles) under slack (low) wind conditions in mountainous settings (complex terrain).

PROJECT PROCEDURES

The methodology was developed, tested and verified using over ten years of excellent and extensive micrometeorological, air quality and tracer data collected in the mountainous Geysers KGRA and the Clear Lake Air Basin.

The MADAM project was conducted by GODDARD & GODDARD ENGINEERING under the direction of the Lake County Air Quality Management District, Robert L. Reynolds, Director and Project Manager John Thompson, Air Quality Engineer. A Guidance Committee was assembled to assist with the project and to ensure that the methodology was scientifically sound and could be used in practical applications. The Guidance committee was comprised of potential users and technical experts, namely: C.E. Woods, (Chairman), Geysers Geothermal Company: Kelly Birkinshaw, California Energy Commission; Mike Cale, GEO Operator Corporation (GRI); Mark Dellinger, Lake County Geothermal Coordinator; Dr. Paul Gudiksen, Lawrence Livermore Laboratory; Matt Haber, Environmental Protection Agency; Ron Knierim, Sacramento Municipal Utility District; Andy Ranzieri, California Air Resources Board; Robert Reynolds, Lake County Air Quality Management District, Director; Steve Sharp, Sonoma County Geothermal Coordinator; Ron Suess, Pacific Gas and Electric Company; Michael Tolmasoff, Northern Sonoma County Air Pollution Control District, Director; and Bob Swan, Mendocino County Air Pollution Control District, Director replaced by Robert Wallen, Mendocino Community College.

The project was approached by dividing the work into five tasks, each of which was defined with a statement of how it was to be accomplished and an approximate time allocated. The work in each task and the results obtained were then presented as a written report and as an oral presentation with illustrations to the Guidance Committee. Each Task Report included

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appropriate graphs, tables, maps and references. The Guidance Committee members responded with their comments and suggestions. There were, therefore, five Guidance Committee meetings and Five Task Reports. At the fourth Guidance Committee meeting, GODDARD & GODDARD ENGINEERING presented to the LCAQMD an administrative version of MADAM including the computer program. Several useful suggestions were made at this time and incorporated into the version 1.0 of MADAM.

Quarterly reports describing the project's progress and copies of each of the five Task Reports and the Project Final Report were submitted to the California Energy Commission's Project Manager, Kelly Birkinshaw. The project commenced in January of 1986 and a Final Report was submitted to the CEC on March 20, 1987.

ACCOMPLISHMENTS

The MADAM project has developed a Personal Computer-based methodology for rapid and accurate assessment of concentration of air pollutants, at ten selected locations (receptors), which are the result of a single emission (pollution) source. MADAM was developed for use in all terrain settings including mountains, valleys, bluffs and flat plains. Plume rise is estimated for various types of emission sources including steam, cooling towers and other gaseous releases. Atmospheric stabilities ranging from extremely unstable through extremely stable are selected for use in estimating plume rise and air dispersion concentrations. The description of the emission source, the weather conditions, the ten receptors and respective elevations are entered by the user, and stored on computer disk files. For another application these files may then be retrieved, the values for any of the 86 input variables modified, and the new variable values stored under a new application name. All algorithms are adjusted within the computer program for their respective elevation, temperature, humidity and wind speeds. All air dispersion concentration estimates are accompanied with an engineering error estimate which indicates their calculated +/- uncertainty. The methodology is restricted to applications where the emission source is near to the receptors (within 10 miles) under slack (less than 10 mph) wind speeds.

The LCAQMD staff has been supplied with the MADAM version 1.0 computer program, and the methodology's Application, User and Reference Manuals. The staff has been trained in a number of MADAM applications and user supported training sessions are planned for the future. This implementation is for the Apple IIe using an Applied Engineering Z80 board. Other MADAM implementations for Apple IIe (with Z80), Macintosh, PCDOS, MSDOS and CP/M personal computers are are available through GODDARD & GODDARD ENGINEERING.

It is expected that appropriate use of MADAM will result in benefits to state and local governmental agencies, industry and the general public, including:

- o making the permitting process more timely by allowing rapid and accurate assessment of air quality impacts;
- o protection of public health by allowing prompt, accurate assessment of air quality impact, especially in those cases where geothermal activity has grown into populated areas;
- o facilitate the prompt and inexpensive permitting of small size (12.5 megawatt) "drop in place" geothermal electric power plants; o more optimal utilization of the available air and geothermal resources and avoidance of those weather conditions leading to severe air quality impact events through geothermal activities management;
- o prompt and timely air quality impact assessment in the site selection planning process; and
- o avoidance of the need for time consuming and expensive tracer tests and sophisticated numerical air quality impact modeling.

MADAM USER SUMMARY OUTLINE
OUTLINE OF THE MADAM METHODOLOGY

INTRODUCTION

MADAM is a single source, multiple receptor air dispersion methodology. If multiple sources are involved such as when a cumulative air quality impact analysis is conducted, then MADAM is applied to each emission source and the results are added at the selected receptors. The source emission may be gaseous and/or particulate emanating from steam, cooling towers or other sources. Particulate matter in emissions are assumed to be small enough so that they have insignificant settling velocities.

STEPS IN THE MADAM METHODOLOGY

1. Source Plume Characterization - all factors effecting plume rise are described as input parameters to the MADAM computer program. Input parameters include: exit stack height, source stack diameter, temperature of the emission, cooling tower diameter and number, molecular weight of

emissions, source steam flow rate, non-steam flow rate, atmospheric pressure, source elevation and reference wind speed, temperature and humidity.

2. Determine the Meteorological Conditions for the source area by review and assembly of all meteorological and climatological data, tracer and other dispersion-related studies available for the area.

3. Topographic Analysis - the topography of the area is studied and maps drawn of all significant features such as mountain peaks and ridges, canyons, steepness of slopes and their compass orientation (aspect), valleys, bluffs and cols noted. All pollution emissions sources and receptors of interest are identified on these maps.

4. Flow Paths of Mesoscale and Local Winds, pertinent to the area of interest are drawn from available data sources on the topographic area map. Maps of estimated wind regimes are drawn for each important type such as night-early morning drainage winds (katabatic) and daytime upslope/upvalley winds (anabatic). The predominance of meteorological features such as marine air intrusion, lake or ocean shore breezes, or river basin local wind developments are shown on these maps.

5. Trajectory Paths are estimated and drawn on each wind regime map of the area for each emission source. Distances are measured and recorded from each emission source along each estimated plume path to a line at right angle to each receptor of interest. At each receptor, the horizontal distance from the receptor location to the plume center line is measured and recorded. This approach constitutes the best estimate of the most probable air quality impact. It is important to consider possible conditions which may cause more severe air quality impacts termed "Worst Case" scenarios. These include a case for mountainous terrain plume impingement where elevated pollutants are lofted to the ground. While plume impingement may occur infrequently, the existence of elevated temperature inversions constrained by topographic features such as valley sides, bluffs or mountain sides can force elevated plumes to the ground. In the Worst Case scenario, it is assumed that pollutants could move in near straight line distances even though the necessary wind patterns may occur infrequently. Worst case scenarios are most suitably presented in tabular form with all assumptions clearly stated.

6. Use of the MADAM Computer Air Dispersion Program can now begin with the selection of the input parameters developed from items 1. through 5. The first MADAM menu prompts for a file of input paramenters. User selections are shown in the following as <> containing the first letter of the choice.

MADAM OPENING MENU

****

ENTER COMMAND <>

<F>ilename WHEN NO CHANGE TO INPUT PARAMETER VALUES NEEDED

<C>hanges CHANGE NEEDED TO INPUT PARAMETER VALUES

<M>anual ENTRY OF INPUT PARAMETER VALUES WHEN NO FILE EXISTS

****

The MADAM program has 86 input parameters which can be specified and stored in an input disk file. Manual entry may be selected by <M>anual although it is often easier to change a similar application input file and then store it under a new file name. If changes are necessary to a file then select <C>hanges. The changes may be stored under a new filename when the user has completed the changes. Select <F>ilename when no changes to the input file is necessary since this then skips the input change menus. If <C>hange or <F>ilename are selected, the user is then prompted for a filename.

FILE NAME PROMPT

ENTER <FILENAME> AND RETURN

The user must enter a valid file name which is on the specified disk drive. If <C>hanges are specified, the input file will be displayed in a series of screens that the user may alter. At the bottom of each input parameter list, a prompt will appear requesting the index number of the parameter that the user wishes to change.

PARAMETER INDEX CHANGE PROMPT

****

ENTER NUMBER - <1 THROUGH 18> FOR VALUE CHANGE, OR <RETURN> FOR DONE

To change an input parameter value, the user enters the Index Number and presses <Return>. The input parameter name and present value appears at the screen bottom. The user then enters the new value and presses <Return>. The new parameter value then appears in the input parameter listing. The user continues to make changes until all of the desired changes are made to that screen. When the user is ready to see the next screen of input parameters, <Return> is entered without an Index Number and the next screen is displayed.

INPUT PARAMETER LIST 1 THROUGH 18

Emission Source and Meteorology

The first 18 input parameters of MADAM describe the emission source and the meteorological conditions occuring during plume transport. MADAM makes all necessary corrections for the altitude of the source and meteorological conditions aloft. Each input parameter is described in the following:

MADAM INPUT PARAMETERS 1 THROUGH 18

SOURCE AND METEOROLOGICAL CONDITIONS

INDEX MADAM INPUT PARAMETER

[1] Source Stack Height, ft
Height at which emissions are released by the source.

[2] Source Stack Diameter, ft
Diameter of source emission release point.

[3] Source Stack Exit Temperature, F
Temperature of source emissions.

[4] Source Cooling Tower Diameter, ft
Diameter of cooling tower exhaust.

[5] Source Number Cooling Tower Cells
Number of cooling tower exhaust fans.

[6] Source Cooling Tower Exit Velocity,fps
Cooling tower exhaust fan exit velocity.

[7] Source Molecular Weight Exiting Gas, g
Average molecular weight of source emissions (Air= 29, Steam= 18).

[8] Source Steam Flow Rate Exiting, lb/hr
Flow rate of steam source emission.

[9] Source Pollutant Emission Rate, lb/hr
Pollutant source emission flow rate - gas or particulates.

[10] Other Source Flow Rate, cfm
Source emissions flow rate other than steam or cooling towers.

[11] Sea Level Atmospheric Pressure, inHg
Standard Sea Level = 29.9 inHg

[12] Source Elevation, ft
Source ground level elevation above sea level.

[13] Reference Wind Speed, mph
Surface wind speed at source and along plume path.

[14] Surface Roughness Coefficient, ft
Typical values are selected from the following:

SURFACE ROUGHNESS COEFFICIENT

Surface,	Height ft,	Roughness ft.
Forest	18	9.3
Orchard Trees	11	6.5
Large City		5.4
Corn Fields	9.8	4.2
Brush	3.0	0.3
Cereal Crops	2.0	0.72
Grass	0.6	0.2
Rough Water		0.06
Smooth Ground		0.0001
Smooth Water		0.0001
Pavement		0.0001

[15] Reference Temperature, F
Surface air temperature at source and along plume path.

[16] Capping Temperature Inversion Height, ftagl
Height at which plume's upward dispersion is trapped.

[17] Reference Relative Humidity, decimal
Surface relative humidity at source and along plume path.

[18] Height Of Meteorological Reference Data, ft
Instrument height at which reference conditions specified.

INPUT PARAMETER LIST 19 THROUGH 58

Receptor Description

The next 40 input parameters of MADAM describe the position of each of the 10 selected receptors in relation to their respective distance along the plume path from the emission source, their respective elevation, their respective horizontal distance away from the plume path center line and their respective height at which the pollutant concentration is to be estimated.

INPUT PARAMETERS 19 THROUGH 58

RECEPTOR 1 THROUGH 10 DESCRIPTION

INDEX MADAM INPUT PARAMETER

[19] Receptor 1 Plume Path Distance, mi
Distance along plume path from the emission source to a line from Receptor 1 normal (at right angle) to the plume path.

[20] Receptor 1 Elevation, ft
Surface elevation above sea level at Receptor 1.

[21] Receptor 1 Plume Horizontal Distance, ft
Horizontal distance from Receptor 1 normal (at right angle) to the plume path.

[22] Receptor 1 Height Above Ground Level, ft
Height above ground at Receptor 1 which pollutant concentration is to be estimated.

[23] through [58] similar for Receptors 2 through 10.

INPUT PARAMETER LIST 59 THROUGH 79

MADAM Air Dispersion Pollutant Concentration Isopleths

Pollutant concentration isopleths data are calculated by MADAM for the General and for the Complex Terrain dispersion applications. The user is required to input the surface elevation along the plume path and the height above the ground at which the isopleths are to be calculated. The user also specifies the 10 desired pollutant concentration isopleths in hourly average parts per billion (ppbv) at which the horizontal distance from the plume center line is to be calculated.

INPUT PARAMETERS 59 THROUGH 79
POLLUTANT CONCENTRATION ISOPLETHS

INDEX MADAM INPUT PARAMETER

[59] Elevation At 0.25 Mile Along Plume Path, ft
Surface elevation below plume path at 0.25 mi from the source.

[60] Elevation At 0.50 Mile Along Plume Path, ft
Surface elevation below plume path at 0.50 mi from the source.

[61] Elevation At 1.0 Mile Along Plume Path, ft
Surface elevation below plume path at 1.0 mi from the source.

[62] Elevation At 1.5 Miles Along Plume Path, ft
Surface elevation below plume path at 1.5 mi from the source.

[63] Elevation At 2.0 Miles Along Plume Path, ft
Surface elevation below plume path at 2.0 mi from the source.

[64] Elevation At 2.5 Miles Along Plume Path, ft
Surface elevation below plume path at 2.5 mi from the source.

[65] Elevation At 3.0 Miles Along Plume Path, ft
Surface elevation below plume path at 3.0 mi from the source.

[66] Elevation At 4.0 Miles Along Plume Path, ft
Surface elevation below plume path at 4.0 mi from the source.

[67] Elevation At 5.0 Miles Along Plume Path, ft
Surface elevation below plume path at 5.0 mi from the source.

[68] Elevation At 6.0 Miles Along Plume Path, ft
Surface elevation below plume path at 6.0 mi from the source.

[69] Isopleth Height Above Ground, ftagl
Height above the ground at which the isopleth concentration estimate is to be calculated.

[70] Isopleth Concentration 1, ppbv
Lowest value of desired pollutant concentration isopleth, for example 4 ppbv.

[71] Isopleth Concentration 2, ppbv
The next desired pollutant concentration isopleth, for example 8 ppbv.

[72] Isopleth Concentration 3, ppbv
The next desired pollutant concentration isopleth, for example 12 ppbv.

[73] Isopleth Concentration 4, ppbv
The next desired pollutant concentration isopleth, for example 16 ppbv.

[74] Isopleth Concentration 5, ppbv
The next desired pollutant concentration isopleth, for example 20 ppbv.

[75] Isopleth Concentration 6, ppbv
The next desired pollutant concentration isopleth, example 24 ppbv.

[76] Isopleth Concentration 7, ppbv
The next desired pollutant concentration isopleth, for example 28 ppbv.

[77] Isopleth Concentration 8, ppbv
The next desired pollutant concentration isopleth, for example 32 ppbv.

[78] Isopleth Concentration 9, ppbv
The next desired pollutant concentration isopleth, for example 36 ppbv.

[79] Isopleth Concentration 10, ppbv
Highest value of desired pollutant concentration isopleth, for example 40 ppbv.

INPUT PARAMETER LIST 80 THROUGH 81

MADAM Valley and Bluff Applications

The Valley and Bluff MADAM applications are used when the valley or bluff sides impede plume horizontal dispersion. The Valley width or the distance to the Bluff from the plume center line are input parameters for these applications.

INPUT PARAMETERS 80 AND 81 VALLEY WIDTH AND BLUFF DISTANCE

INDEX	MADAM INPUT PARAMETER
[80]	Distance Across Valley , mi Distance across the valley along which the plume path follows.
[81]	Distance To Bluff, mi Distance from plume path center line to the Bluff.

INPUT PARAMETER LIST 82 THROUGH 86

Estimation of Errors
MADAM Dispersion Estimates

All of the air dispersion estimates made by MADAM are accompanied by a +/- value. This value is a calculation of the 68% probability, assuming random and normally distributed errors, that the MADAM estimate lies between those +/- bounds. Percentage uncertainties are user inputs for the following dispersion variables:

INPUT PARAMETERS 82 THROUGH 86
ASSIGNMENT OF PARAMETER UNCERTAINTIES

INDEX	MADAM INPUT PARAMETER
[82]	Source Pollutant Emission Rate Uncertainty, decimal Percentage error estimate of uncertainty in the pollutant emission rate.
[83]	Wind Speed Uncertainty, decimal Percentage error estimate of the uncertainty in the reference wind speed.
[84]	Horizontal Dispersion Coefficient Uncertainty, decimal Percentage error estimate of the uncertainty in the horizontal dispersion coefficient Sigma Y.
[85]	Vertical Dispersion Coefficient Uncertainty, decimal Percentage error estimate of the uncertainty in the vertical dispersion coefficient Sigma Z.
[86]	Plume Rise Height Uncertainty, decimal Percentage error estimate of the uncertainty in the plume rise height estimate.

USER PROMPT FOR NEW OR OLD INPUT FILE NAME

Upon completing the changes desired to the MADAM input parameters, a menu will appear requesting a new file name or an option for the changes to be stored in the original file.

```
****************************************
EITHER ENTER NEW <FILENAME> AND  PRESS
      RETURN FOR NEW DISK FILE

OR ENTER <F>inished FOR PARAMETER DISK
      FILE IN ORIGINAL FILENAME
****************************************
```

If the user desires to store input parameter changes under the original file name then select <F>inished. For a new file name enter the new file name then <RETURN>. The file name convention allows 8 letters followed by a 3 letter prefix (for example, POWERPLT.IPT) If the input file was entered manually, then the prompt will only include a request for a file name.

EMISSION SOURCE TYPE SELECTION

The user is asked to select either <S>team, <C>ooling Towers or <O>ther from the list of Emission Sources.

```
****************************************
       PLUME RISE CALCULATIONS
        SELECT DESIRED CASE
****************************************
   SELECT TYPE OF EMISSION SOURCE
           ENTER COMMAND
<S>team, <C>ooling Tower, <O>ther Source
****************************************
```

ATMOSPHERIC STABILITY SELECTION

The user is requested to choose the Pasquil Atmospheric Stability Class A through G. The atmospheric stability classes are described by typical examples of temperature profiles aloft and typical horizontal wind direction standard deviation, Sigma. A typical day will begin with stable conditions in the early morning followed by neutral in mid morning then unstable through late afternoon. Neutral will again occur in the early evening with increasing more stabile conditions throughout the night. The relationship between weather conditions and stability classification are described in the following:

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RELATIONSHIP OF ATMOSPHERIC STABILITY CLASSES TO WEATHER CONDITIONS

CLASS	CLASS
A - Extremely Unstable Conditions	D - Neutral Conditions *
B - Moderately Unstable Conditions	E - Slightly Stable Conditions
C - Slightly Unstable Conditions	F - Moderately Stable Conditions
	G - Extremely Stable Conditions

Surface Wind peed, mph	Daytime Sunlight Strong	Moderate	Slight	Nighttime Conditions Cloud Cover** >= 1/2	< 3/8	Clear
< 4.5	A	A-B	B	E	F	G
4.5	A-B	B	C	E	F	G
9.0	B	B-C	C	D	E	F
13	C	C-D	D	D	D	E
> 13	C	D	D	D	D	D

* Applicable to heavy overcast and marine intrusion, day or night

** Cloudiness is defined as that fraction of the sky above the local horizon which is covered by clouds.

The selection is made by the user of a stability class <A> through <G> from the following menu:

ATMOSPHERIC STABILITY CLASSIFICATION

SELECT DESIRED CLASS

****

ENTER COMMAND - Select Atmospheric Stability Classification

Atmospheric Stability Class	Typical Temperature Gradient C / 100 m	F / 1000 ft	Wind Sigma Degrees
<A> - Extremely Unstable	< - 1.9	< - 17.5	25
<B> - Moderately Unstable	- 1.9 to <- 1.7	- 10.4 to <- 9.3	20
<C> - Slightly Unstable	- 1.7 to <- 1.5	- 9.3 to <- 8.2	15
<D> - Neutral	- 1.5 to <- 0.5	- 8.2 to <- 2.7	10
<E> - Slightly Stable	- 0.5 to < 1.5	- 2.7 to < 8.2	5
<F> - Moderately Stable	1.5 to < 4.0	8.2 to < 22	2.5
<G> - Extremely Stable	> = 4.0	> = 22	< 2.5

****

MADAM REPORT SELECTIONS

MADAM Output Reporting Selection Menu

The <S>creen selection refers to reporting results on the computer console only with no recorded record. The <P>rinter selection allows a hard copy to be printed immediately. The <T>ext File option writes results to an ASCII disk file for later printing or word processing. The Text file option is followed by a prompt requesting a file name. The Printer and Text file options report all results also to the computer console. The Printer and Text file options both record the MADAM input parameters as well as the MADAM results. After the user selects the desired mode of reporting, MADAM will proceed with the report.

MADAM REPORTING MODE SELECTION MENU

****

SELECT DESIRED MODE FOR MADAM OUTPUT

ENTER COMMAND - OUTPUT TO <S>creen, <P>rinter, <T>ext File

****

MADAM PLUME RISE REPORT

The plume rise report lists the type of emission source and the stability condition. The buoyancy plume rise is listed above ground level. Additional plume rise occurs due to the heat of condensation from moisture and is listed as a percent. The jet effect of the released emission source is listed as the momentum plume rise. The conditions aloft which are calculated from the surface reference conditions are listed as the average wind speed and temperature aloft. The reference wind speed and temperature are also listed.

MADAM CASE SELECTION

Selection of the desired MADAM application case depends upon the topographical terrain features. The <G>eneral case is intended for gently rolling and flat topography or for cases where the plume follows the terrain features. The <C>omplex Terrain case is intended for mountainous terrain where plume impingement may occur. The <V>alley case is intended for situations where the valley sides impede plume dispersion. The <B>luff case is intended for cases where a bluff impedes plume dispersion. The <F>umigation case is intended for situations where pollutants disperse into stable air and then are later mixed to the surface receptors.

MADAM REPORT LENGTH

The user may select from the MADAM reporting selection menu an <A>bstract summary or <F>ull report on each of the 10 receptor locations.

MADAM <F>ull reporting output lists the Receptor distance along the plume transport path and the pollutant concentration above ambient in ug/m**3 which is then converted, using the Receptors elevation and temperature, to ppbv. Hourly conversions are listed where the MADAM few minute average is multiplied by 0.61 to convert to an hourly average. The remaining details of the estimate include the receptor elevation, the inversion height, the distance from the receptor along a normal line to the plume path, the height at which the pollutant concentration was calculated, the stack level wind speed and the Gaussian dispersion coefficients Sigma Y and Sigma Z.

An <A>bstracted hourly summary reporting is available to the user who does not want all of the information contained in full reporting.

If longer averaging times are desired, the concentration estimates of MADAM may be multiplied by the following:

ACKNOWLEDGEMENT

We appreciate the able assistance of William R. Knuth, Meteorologist, on the MADAM project.

AVERAGING TIME VERSUS MADAM ESTIMATES

AVERAGING TIME	MULTIPLY MADAM ESTIMATE BY
3 TO 10 MINUTES	1.0
15 MINUTES	0.82
1.0 HOUR	0.61
3.0 HOURS	0.51
24 HOURS	0.36

Note: Hourly averages reported by MADAM have been obtained by multiplying by 0.61.

MADAM POLLUTION CONCENTRATION ESTIMATES ISOPLETHS

The user has the choice of <G>eneral or <C>omplex Terrain isopleths of concentration, or <N>o for program end.

Each of ten locations are reported from which isopleths of the selected hourly ppbv concentrations may be plotted. Each of the 10 locations, 0.25, 0.50, 1.0, 1.5, 2.0, 2.5, 3.0, 4.0, 5.0 and 6.0 mi, are reported separately. The isopleth report lists the height at which estimates were calculated as 32.8 ft (10 m) above the surface. The plume center line hourly concentration, above ambient, at this height is listed in ppbv. The horizontal distance normal to the plume centerline out to the desired isopleth is listed for ten user selected intervals such as from 4 to 40 ppbv.

From the isopleth report of the ten locations along the plume path, the user can plot the distance normal to the plume path center line out to each desired concentration isopleth. Interconnection of these points for each of the selected hourly above ambient concentrations produces an isopleth for each desired concentration.

CONCLUSION

This concludes the condensed summary of MADAM features. We encourage all interested parties to obtain a copy and use the methodology to assist them in their air quality impact assessment needs.

All those interested in a training seminar on MADAM which will be conducted late summer or early fall are encouraged to contact GODDARD & GODDARD ENGINEERING.

APPENDIX B

KS8 WELL VENTING HEALTH COMPLAINTS AND SYMPTOMS DATA

ACKNOWLEDGEMENTS

Big Island Rainforest Action Group ... Printed and distributed surveys in the communities affected and collected completed forms

Colleen Mandala ... Pahoa Natural Foods -- circulated a health survey compiled by a medical doctor and collected responses from area residents

Kapoho Community Association ... mapped locations of affected residents from health surveys
-- plotted possible wind flow
-- collated health surveys into statistical data for each subdivision or area impacted

HEALTH SURVEY SUMMARY FROM BIRAG AND PAHOA EMPORIUM QUESTIONNAIRES FOR KS-8 BLOWOUT OF JUNE 12, 1991.

CODE NO.	SUBDIVISION NAME	NO. OF FORMS
1	Puu Honuaula	4
2	Lanipuna	12
3	Pohoiki Bay Estates, Leilani	37
4	Opihikao Homesteads	12
5	Puna Palisades	3
6	Kehena	4
7	Kalapana Seaview Estates	9
8	Black Sands Subdivision	9
9	Upper Kaimu Homesteads	1
10	Kamaili Homesteads	4
11	Kaohe	3
12	Ainaloa, Orchidland	2
13	Hawaiian Acres	2
14	Hawaiian Paradise Park	4
15	Hawaiian Beaches, Hawaiian Shores	2
16	Pahoa, Nanawale	9
17	Kapoho	7

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Odor of Sulfur	4	11	29	11	2	4	9	8	1	4	2		1	3	1	6	4
Loss of Smell/Taste		2	3			1											
Eye Irritation	5	10	26	8			3	4	1	1	3		1	4	2	4	2
Nose Irritation	1	4	9	1			1	1			2			2		1	2
Throat Irritation	6	10	19	7	1	3	7	2		4	3	1	1	4	2	4	3
Trouble Breathing	3	5	11	8		2	5	2		2	2	1		2		3	2
Coughing Wheezing	2	5	11		1			1			1			2			1
Hyperexcitability	2	1	2					1									
Insomnia/ Trouble Sleeping	1	4	8	2	1			1		1	2	1	1	1		2	
Headaches	6	9	27	10	3	2	6	4		3	3	1	2	4	1	6	4
Earaches	2	1	4	1			1	1						1			2
Dizziness	5	6	14	3		1	4	1				1		2		4	4
Loss of Balance/		1	5					1									
Staggering														1			
Weakness	1	3	8	1	1			1			1						
Rash/Skin Irritation	8	2	5	2		1	1	1		1	1	1	1				1
Hair Loss			2														
Joint or Muscle Pain		3	5		1		1	1						1			
Nausea	2	4	7	1	1		1	1			2			2			2
Upset Stomach	1	8	9	5	1	2	5	2	1		1	1		1		5	
Vomiting	1	2	3				1	1				1		1			
Diarrhea		2	6				1	1						1			
Loss of Appetite	1	2	5		1			1						1			1
Weight Loss		1	2				1							1			
Low Blood Pressure																	
Anxiety	2	6	13	2			1	2	1		1					1	2
Panic Attacks	2	1	7	2				2			1						1

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Lethargy/No Energy/ Sluggish	1	3	8	1	1			1			1			2			1
Heart Palpitations	1	1	2												1		
Chest Pains	1	1	6											1	1		
Shortness of Breath	1	1	7	1				1			1			1			1
Seizures			1														
Coughing up Blood			1														
Blood in Urine/Stool			1				1				1						
Sulfur Odor in Urine /Stool	1																1
Irregular Mensis	1	1	3					1									
Fever			1											1			1
Mucous		1	2														
Medical Care	1	3	3	1							1			1			1
Heard venting noise	4	8	20	12	2	3	8	6	1	4	2	2	1	2	1	8	3
Noise irritating	4	8	20	11	2	2	8	6	1	4	2	2	1	2	1	7	2
Water catchment	4		20	12	2	4	8	6	1	4	2	2	1	2		3	4
Fallout on roof	2	3	6	2		1	1	2		1	1					4	1
Car damage	2	1	1													1	
Animals/Plants	4	4	6				2				1						

OTHER COMMENTS:

Nightmares (Opihikao, Nanawale

Gray spots on clothing in Leilani on 6/13 12:30 pm

Two weeks of illness from driving by plant twice in one day.

One child had fever and numb right side (leg & arm). Nohea St.

Whenever husband smells sulfur he vomits. Was worse with HGPA leaks. Feel weak a lot. Mohala St.

Dead bird, dying butterflies (Nanawale

Birds left. Opihikao

No officials able to tell about effect on water catchment. Came home on 6/16. Hookupu St.

Average 80 dba for 30 hours. Pohoiki Bay Estates

Dogs howling all night. Nohea St.

I can't believe that Puna is in America. Leilani Ave.

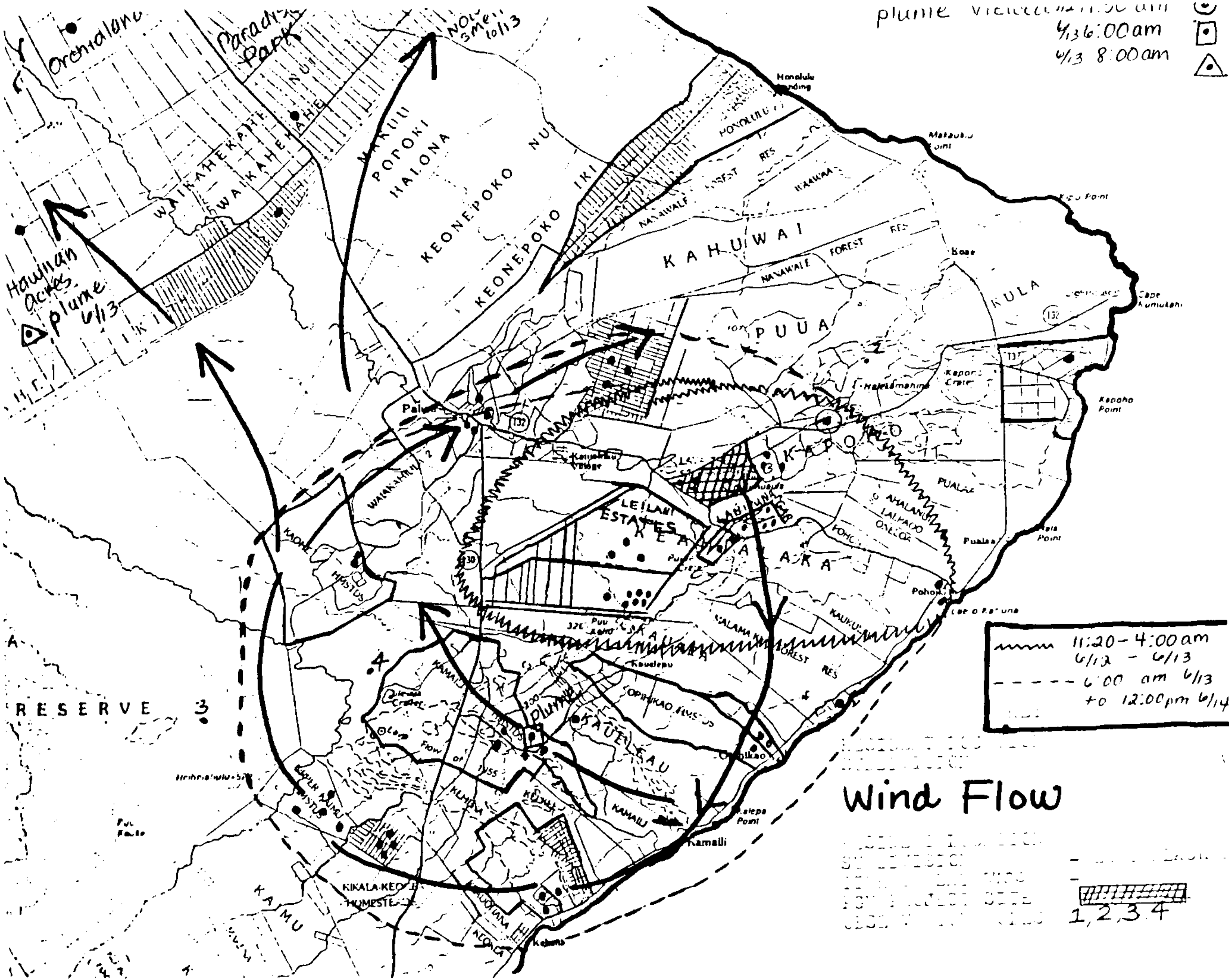
Chickens staggering. Puu Honuaula

Eye Infections, extreme fear/acting crazy. Animals vomiting and acting weird. Puu Honuaula

Vomit, diarrhea. black feces, eyes shut tight with mucuous. Puppy's stool bloody and projectile, died by end of day. During abated vent felt sluggish, drifting off, not concentrating; mouth feels strange, taste is gone, get light throaty cough, stomach feels floaty (maybe vomit, maybe not), caustic soda smell can give a headache in minutes. Hinalo St.

Swollen and sore glands in throat and arm pits 5 year old child. Hinalo

Depression, crying over 24 hours. Dogs lethargic, not eating. Still have a feeling of fear and no peace in our own home. Hinalo St



Wind Flow
plume
6/13 6:00am
6/13 8:00am
11:20-4:00am 6/12 - 6/13
6:00 am 6/13 to 12:00pm 6/14
Orchidland
Paradise Park
Hawaiian Acres plume 6/13
WAIKAHEKAHE
POPOKI
HALONA
KEONEPOKO NUI
KEONEPOKO IKI
KAHUWAI
NANAWALE FOREST RES
PUUA
KAPOHO
LEILANI ESTATES
KEAUOHANA
KAUELEAU
OPIHIKAO
MALAMA KI FOREST RES
KIKALA-KEOKEA HOMESTEADS
RESERVE
Honolulu Landing
Kapoho Point
Kapoho Crater
Cape Kumukahi
Pahoa
Kamaili
Kehena
Opihikao
Kaueleau
Pualaa
Lae o Karuna
Pu'u Kohola
1, 2, 3, 4

APPENDIX C

OPERATIONAL MANAGEMENT OF AIR RESOURCES

(OMAR)

Geothermal Resources Council TRANSACTIONS Vol. 14 Part I August 1990

AIR QUALITY COMPLIANCE IMPROVEMENTS THROUGH OPERATIONAL MANAGEMENT OF AIR RESOURCES (OMAR)

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ABSTRACT

Geothermal well fields and power plants require operational and emergency atmospheric venting. Venting activities are monitored for compliance with regulations which limit air pollutant emissions and Ambient Air Quality Standards (AAQS). Continuous compliance monitoring data which includes hydrogen sulfide (H2S) levels and meteorological conditions is only available months after being compiled.

An automated computerized system called OMAR is described in the following which checks data and allows users access to real-time and near real-time data reports. The data can then be used for managing necessary venting or other real-time data needs.

The OMAR system hardware and software is described and is in use at The Geysers and at the Coso KGRA geothermal developments in California. The system has been designed to assist developers, engineers, scientists, and the local air districts in their goal of maintaining ambient air quality within Federal, State and Local standards.

INTRODUCTION

In the spring of 1987, Goddard & Goddard Engineering (G&GE) proposed the project termed OMAR which would develop an automated computerized system to check real-time data and make available to users near real-time data reports. It was proposed that the OMAR project be managed by the Lake County Air Quality Management District (LCAQMD) and funded by the California Energy Commission's (CEC) Geothermal grant program. A formal contract was signed by G&GE on May 23, 1988 to begin work on the project.

A similar OMAR project was proposed to the California Energy Company, Inc. (CECI) in the spring of 1988 and final approval was given in November 1989 for the system design and deployment.

The goal of the research and development project was to automate use of air quality and meteorological (aerometric) compliance monitoring data which would then be available for managing necessary geothermal venting operations at The Geysers and at the Coso developments. Participating parties included the LCAQMD, CECI, CEC, the Northern Sonoma County Air Pollution Control District (NSCAPCD), and the Great Basin Unified Air Pollution Control District (GBUAPCD). Automated computer access has been or is planned at LCAQMD, NSCAPCD, GBUAPCD and at the CECI Coso Division headquarters (Goddard, 1989).

While industry has carried the financial costs of these necessary compliance monitoring programs, the data has not been available in real or near real-time. Data reports have only been available on a quarterly basis after months of data auditing and passing thorough quality assurance standards (QA). While QA procedures are necessary, this has not allowed real-time access to these data.

The OMAR project has resulted in allowing users access to the compliance monitoring data for use in managing activities which include necessary venting, planning operations and construction work and specialized studies which require these data.

OMAR SYSTEM DESIGN AND OPERATION

An organizational diagram of OMAR is shown in Figure 1. Aerometric sensors including wind speed, wind direction, air temperature and humidity, precipitation and H2S concentration are monitored by Campbell Scientific Inc. (CSI) data loggers. The CSI data loggers can record up to 5 months of data unattended. The CSI data loggers are programed to collect 3 minute peaks, Sigma (standard deviation of wind direction), hourly averages and running totals for precipitation.

The CSI data loggers are accessed via modems through telephone lines and radio telemetry. The loggers are programed to automatically send an out-of-range alarm data reports to the remote OMAR computer if the 3 minute peak H2S concentration exceeds a decision threshold criteria (nominally 20 ppb).

Access to the CSI data loggers is initiated from the remote OMAR computer at a short interval (nominally 1 hour), or upon receipt of an out-of range alarm report from one CSI monitoring site or by a local OMAR computer users.

OMAR Hardware and Software Description

The main elements of the OMAR hardware and software components are shown in Figure 2. IBM 386 compatible computers which operate reliably in a true multi-tasking mode are used for local and the remote computers.

The remote computer is installed near enough to the CSI aerometric monitoring sites that efficient and cost effective frequent communication can be obtained. The remote computer is equipped with a CSI clock-SIO and power-up board which turns the computer off and then on again (cold boots) in cases where the computer hangs-up or in cases where communication links become tied-up. This hardware/software equipment is necessary where computers run remotely to avoid manual restarts.

Each participating OMAR user must have a dedicated local computer (or one with multi-tasking capabilities) which is IBM compatible. The local multi-tasking function allows the user to use the computer for running their general purpose programs while the OMAR programs operate in the background.

The software used for this purpose is Quarter Deck's Desqview(1). Desqview can have as many as 9 programs all running at once depending on memory size. Procomm(2) is used by both the remote and local computers to automatically telecommunicate. Two CSI programs Telcom(3) and Split(3), are used timing, coordination and data processing. Quatro(4), a spreadsheet program by Borland International, is used for data graphical display. Several programs which check data and coordinate activities where developed for OMAR. A site-specific version of MADAM is used for the air dispersion assessments (Goddard, 1988).

Functions of the Remote OMAR Computer

The remote OMAR computer serves as a remote node with communication links to each CSI data logger monitoring site and with a communication link to the local OMAR computer users. The functions of the remote OMAR computer are shown in Figure 3.

The remote functions include receiving out-of-range alarm reports from the CSI monitoring sites, compiling out-of-range alarm reports, archiving short term (nominally 1 hour) near real-time data reports and archiving monitoring data in report form. When data is found to be out-of-range an alarm report is immediately sent to each local OMAR computer.

The remote OMAR computer, upon receiving an CSI logger alarm data report, automatically initiates a program which accesses all the OMAR CSI sites and performs an out-of-range data check. If the check finds data out-of-range (nominally 15 ppb 15 minute average), the remote OMAR computer automatically sends an out-of-range alarm report to the local OMAR computers.

The remote computer automatically polls (calls) each CSI monitoring site each hour (nominally) and downloads the last hour's data from each site. An out-of-range data check is made and the data is archived in a short term report and in a long term data archive.

Once a day a 24-hour data summary is sent to each local OMAR computer. These summaries are used to assist in maintaining quality assurance, increased data capture rates and for general operational needs.

Upon receipt of a command from the local OMAR computer, the latest near real-time data report is sent to the local computer. Long term data archives are sent to the local OMAR computer when requested.

Local OMAR Computer Functions

The local OMAR multi-tasking computers can be used to run general purpose programs as well as running OMAR programs in the background. The OMAR functions are shown in Figure 4. Programs automatically answer incoming calls from the remote OMAR computer to receive data reports, alarm reports (which beep on receipt) and long term archived data reports. On command programs display numerical and graphical data reports and perform air dispersion assessments.

OMAR Air Dispersion Assessments

Each OMAR installation has been designed to monitor conditions at and near receptors of concern and at sites of meteorological interest. The system design provides the necessary near real-time data needed to run air dispersion assessments for emission sources of concern.

Ridge top and/or mountain top stations are used to determine the state of atmospheric stability, the presence of marine air intrusion and/or subsidence capping temperature inversions. A station on the Mayacmas Mountain ridge at The Geysers and a station on top of Sugar Loaf Mountain at Coso are used for this purpose.

When a user requests an air dispersion assessment from the local OMAR computer, the first operation that is performed is the retrieval of the latest near real-time data report from the remote OMAR computer. The data is then processed to determine the present meteorological conditions and whether good or poor air dispersion conditions exist.

The user enters the location of the necessary venting operations in UTM coordinates, the elevation and the type of emission source. The OMAR air dispersion program will then estimate the incremental impact of the venting above ambient concentrations of H2S and the cumulative impact base on the monitored ambient H2S levels.

The user can run several venting scenarios including decreases in existing venting from bleeding or testing wells, or other emission sources. While users must obtain local air district permission to surpass venting emission limits, they can use OMAR as a management tool in demonstrating that venting will not result in substantial increased H2S levels.

OMAR will assist in avoiding poor air dispersion impacts when emergency venting break-downs occur. Users can immediately determine what the ambient levels of H2S are and reduce venting of manageable emissions so that impacts are maintained well below AAQS.

SUMMARY AND CONCLUSIONS

The OMAR system allows access in real-time to compliance monitoring data for use in making management decisions concerning necessary geothermal venting operations. The real or near real-time data is coupled to site specific complex terrain air dispersion models to yield impact assessments. The venting impact assessments allow various venting scenarios to be evaluated using actual near real-time air quality and meteorological data.

Decreased ambient air quality throughout the world especially near urban centers has led to agencies increasing the punitive penalties for exceeding emission limits and/or exceeding AAQS. The California Clean Air Act mandates three year attainment (no exceed of an AAQS) before conferring attainment status. Non-attainment areas must provide air quality impact offsets which may not be available and are always expensive.

Geothermal energy has proved itself to be environmental compatible. The geothermal industry in California has proven its ability to operate competitively within the stringent H2S CAAQS of 42 ug/m3 (0.03 ppm) and OMAR enhances this ability.

REFERENCES

Goddard, W.B. and C.B. Goddard, Oct 1989 Use of Required Air Compliance Monitoring for Management of Necessary Venting - a Project Initiated at The Geysers - Applications and Development of Operational Management of Air Resources (OMAR), Geothermal Resources Council, TRANSACTIONS Vol 13 Davis, CA

Goddard, W.B. and C.B. Goddard, Oct 1987 Micrometeorological Air Dispersion Assessment Methodology (MADAM), A Geothermal Air Quality Impact Assessment Toolbox Available As Shareware, Geothermal Resources Council, TRANSACTIONS, Vol. 11, Davis, CA

Note:
(1) Desqview is a product of Quarter Deck Office Systems, Santa Monica, CA
(2) Procomm is a product of Datastorm Technologies, Columbia, MO
(3) Telcom and Split are products of Campbell Scientific, Logan UT
(4) Quatro is a product of Borland International, Scotts Valley, CA

Goddard, W.B. and C.B. Goddard

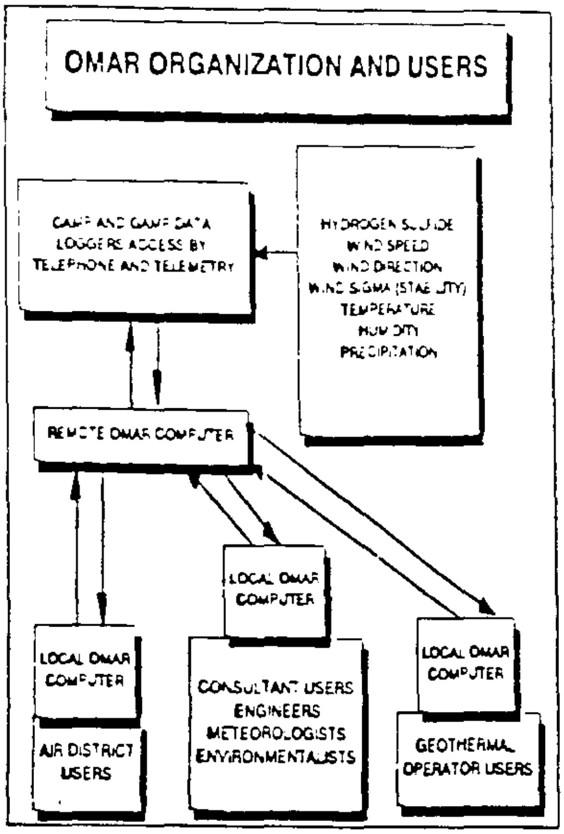

FIGURE 1: OMAR ORGANIZATION AND USERS

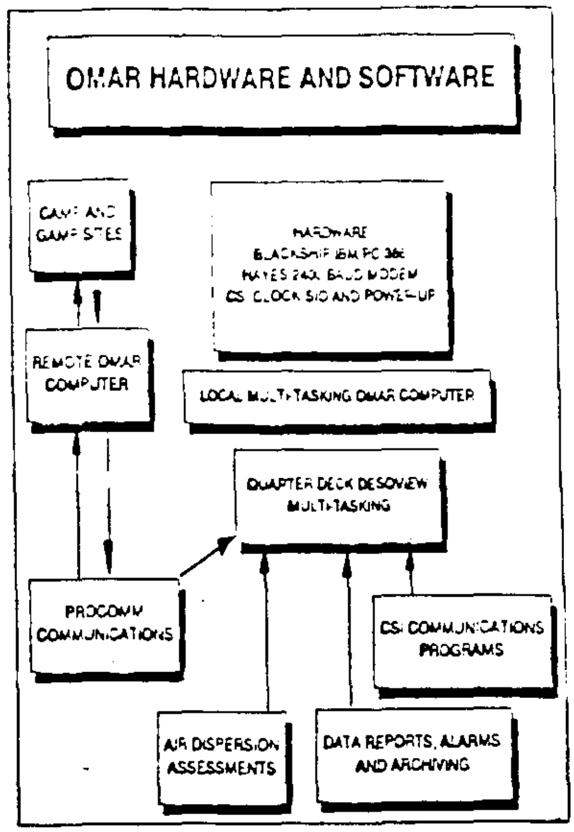

FIGURE 2: OMAR HARDWARE AND SOFTWARE

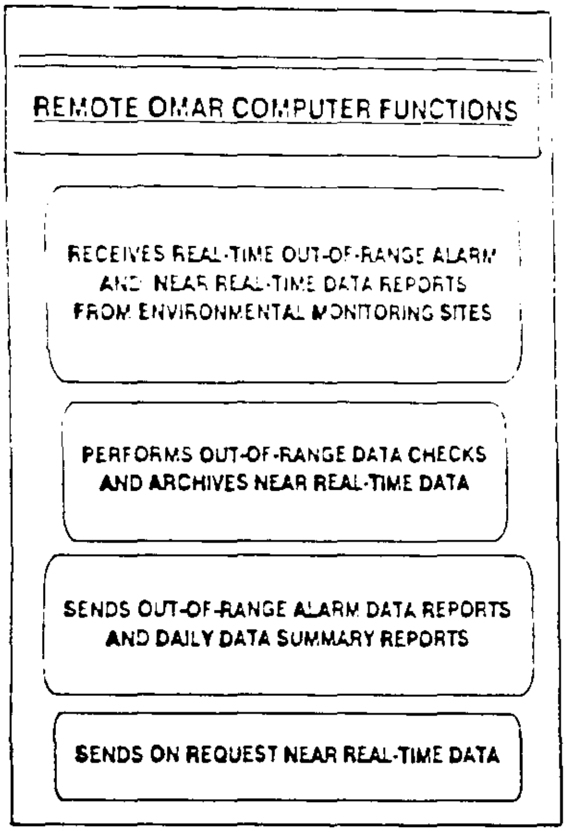

FIGURE 3: REMOTE OMAR COMPUTER FUNCTIONS

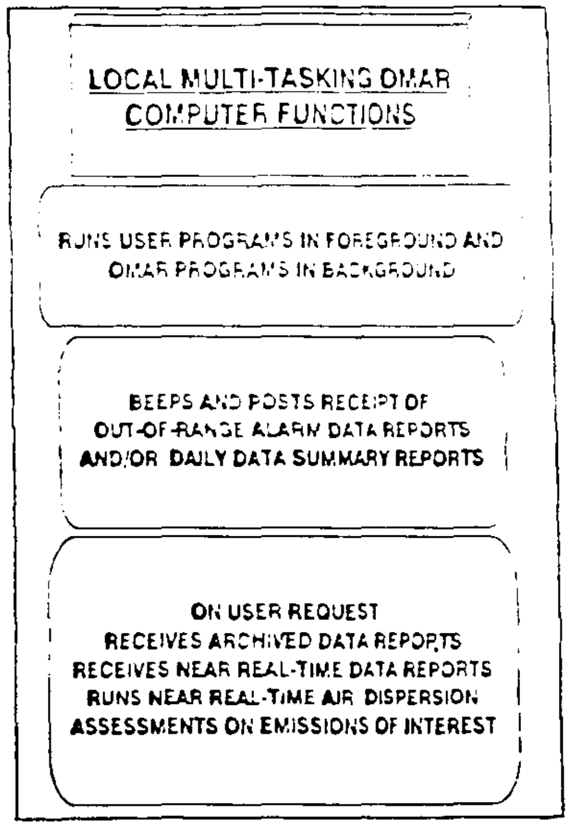

FIGURE 4: LOCAL MULTI-TASKING OMAR COMPUTER FUNCTIONS